CHAPTER 37

SWAT INPUT DATA: LAND/WATER MANAGEMENT

A primary goal of environmental modeling is to assess the impact of anthropogenic activities on a given system. Central to this assessment is the itemization of the land and water management practices taking place within the system. SWAT utilizes two files to summarize these practices within the HRUs, the HRU management file (.mgt) and the subbasin water use file (.wus).

37.1 MANAGEMENT INPUT FILE (.MGT)

This file contains input data for planting, harvest, irrigation applications, nutrient applications, pesticide applications, and tillage operations.

Operations may be scheduled by month and day or by heat units. If both month/day and heat units are given for a scheduled operation, the model will implement the operation on whichever occurs first. For example, assume a fertilizer operation is scheduled for April 1 or a heat unit index of 0.3. In year one, the heat unit index of the crop reaches 0.3 on April 14 while in year two the heat unit index of the crop reaches 0.3 on March 25. SWAT will apply the fertilizer on April 1 the first year and March 25 the second year.

SWAT calculates two different heat unit indices throughout a year. The first is a base zero, or annual, heat unit index for the HRU. The total heat units that can be accumulated annually is equal to the sum of degrees C above 0˚C in the daily mean temperature for every day of the year. Throughout each year of simulation, an index is calculated which tells the fraction of the total heat units accumulated. The base zero, or annual, heat unit index is reset to zero on January 1st. This heat unit index is used to schedule operations when no plant is growing.

The second heat unit index calculated by SWAT is the plant heat unit index. The base temperature for the plant heat unit index is the minimum temperature required by the plant for growth. The total number of heat units required to bring the plant to maturity, referred to as the potential heat units, is equal to the sum of degrees C above the plant base temperature in the daily mean temperature for every day of the plant growing season. The plant heat unit index is calculated only when something is growing in the HRU.

37.1.1 GENERAL MANAGEMENT VARIABLES

The first two lines of the management input file contain general management variables. The remaining lines in the file list the sequence of management operations which occur throughout a year of simulation.

The general management variables are:

Variable name	Definition
TITLE	The first line of the .mgt file is reserved for user comments. The comments may take up to 80 spaces. (optional)
IGRO	Land cover status code. This code informs the model whether or not a land cover is growing at the beginning of the simulation. 0 no land cover growing 1 land cover growing
NROT	Number of years of rotation. This code identifies the number of years of management practices given in the .mgt file. (A blank line should be inserted between each different year of management.) If the management doesn't change from year to year, the management operations for only one year are needed. Two land covers/crops may not be grown simultaneously, but they may be grown in the same year. For two or more crops grown in the ***same*** year, NROT is equal to 1 for 1 year of management practices listed. NROT has nothing to do with the number of different crops grown.
NMGT	Management code. Used by SWAT/GRASS (GIS) interface. The model doesn't use this variable.
NCRP	Land cover identification number. If a land cover is growing at the beginning of the simulation (IGRO = 1), this variable defines the type of land cover. The identification number is the numeric code for the land cover given in the crop.dat file.
ALAI	Initial leaf area index. If a land cover is growing at the beginning of the simulation (IGRO = 1), the leaf area index of the land cover must be defined.
BIO_MS	Initial dry weight biomass (kg/ha). If a land cover is growing at the beginning of the simulation (IGRO = 1), the initial biomass must be defined.
PHU	Total number of heat units or growing degree days needed to bring plant to maturity. This value is needed only if a land cover is growing at the beginning of the simulation (IGRO = 1).

Variable name	Definition
BIO_MIN	Minimum plant biomass for grazing (kg/ha). Grazing will not be simulated unless the biomass is at or above BIO_MIN.
BIOMIX	Biological mixing efficiency. Mixing of the soil due to activity of earthworms and other soil biota. Mixing is performed at the end of every calendar year. If no value for BIOMIX is entered, the model will set BIOMIX = 0.20
CN2	Initial SCS runoff curve number for moisture condition II. The curve number may be updated in plant, tillage, and harvest/ kill operations. If CNOP is never defined for these operations, the value set for CN2 will be used throughout the simulation. If CNOP is defined for an operation, the value for CN2 is used until the time of the operation containing the first CNOP value. From that point on, the model only uses operation CNOP values to define the curve number for moisture condition II. Values for CN2 and CNOP should be entered for pervious conditions. In HRUs with urban areas, the model will adjust the curve number to reflect the impact of the impervious areas.
USLE_P	USLE equation support practice (P) factor. The ratio of soil loss with a support practice like contouring, stripcropping, or terracing to that with straight-row farming up and down the slope.

The format of the first two lines in the management file are:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	space 1-80	character	a80
IGRO	2	space 1	1-digit integer	i1
NROT	2	space 2-4	3-digit integer	i3
NMGT	2	space 5-8	4-digit integer	i4
NCRP	2	space 9-12	4-digit integer	i4
ALAI	2	space 13-20	decimal (xxxxx.xx)	f8.2
BIO_MS	2	space 21-28	decimal (xxxxx.xx)	f8.2
PHU	2	space 29-36	decimal (xxxxx.xx)	f8.2
BIO_MIN	2	space 37-44	decimal (xxxxx.xx)	f8.2
BIOMIX	2	space 45-52	decimal (xxxxx.xx)	f8.2
CN2	2	space 53-60	decimal (xxxxx.xx)	f8.2
USLE_P	2	space 61-68	decimal (xxxxx.xx)	f8.2

37.1.2 SCHEDULED MANAGEMENT OPERATIONS

SWAT will simulate 14 different types of management operations. The first four variables on all management lines are identical while the remaining ten are operation specific. The variables for the different operations will be defined in separate sections. The type of operation simulated is identified by the code given for the variable MGT_OP.

The different codes for MGT_OP are:

1	**planting/beginning of growing season:** this operation initializes the growth of a specific land cover/plant type in the HRU
2	**irrigation operation:** this operation applies water to the HRU
3	**fertilizer application:** this operation adds nutrients to the soil in the HRU
4	**pesticide application:** this operation applies a pesticide to the plant and/or soil in the HRU
5	**harvest and kill operation:** this operation harvests the portion of the plant designated as yield, removes the yield from the HRU and converts the remaining plant biomass to residue on the soil surface. It also sets IGRO = 0 which allows the next crop to be planted.
6	**tillage operation:** this operation mixes the upper soil layers and redistributes the nutrients/chemicals/etc. within those layers
7	**harvest only operation:** this operation harvests the portion of the plant designated as yield and removes the yield from the HRU, but allows the plant to continue growing. (this operation is used for hay cuttings)
8	**kill/end of growing season:** this operation stops all plant growth and converts all plant biomass to residue. It also sets IGRO = 0 which allows the next crop to be planted.
9	**grazing operation:** this operation removes plant biomass at a specified rate and allows simultaneous application of manure.
10	**auto irrigation initialization:** this operation initializes auto irrigation within the HRU. Auto irrigation applies water whenever the plant experiences a user-specified level of water stress.
11	**auto fertilization initialization:** this operation initializes auto fertilization within the HRU. Auto fertilization applies nutrients whenever the plant experiences a user-specified level of nitrogen stress.
12	**street sweeping operation:** this operation removes sediment and nutrient build-up on impervious areas in the HRU. This operation can only be used when the urban build up/wash off routines are activated for the HRU.
13	**release/impound:** this operation releases/impounds water in HRUs growing rice or other plants
0	**end of year rotation flag:** this operation identifies the end of the operation scheduling for the year.

The operations must be listed in chronological order starting in January.

37.1.2.1 PLANTING/BEGINNING OF GROWING SEASON

The variables which may be entered on the planting line are listed and described below

Variable name	Definition
MONTH	Month operation takes place.
DAY	Day operation takes place.
HUSC	Fraction of total base zero heat units at which operation takes place. (If MONTH and DAY are not provided, HUSC must be set to a value)
MGT_OP	Management operation number. MGT_OP = 1 for planting/beginning of growing season
HEAT UNITS	Total heat units for cover/plant to reach maturity.
NCR	Land cover/plant identification number from crop.dat.
HITAR	Harvest index target ((kg/ha)/(kg/ha)) (optional). This variable along with BIO_TARG allow the user to specify the harvest index and biomass produced by the plant every year. The model will then simulate plant growth to meet these specified values. If you are studying the effect of management practices on yields or you want the biomass to vary in response to different weather conditions, you would not want to use HITAR or BIO_TARG.
BIO_TARG	Biomass (dry weight) target (metric tons/ha) (optional). This variable along with HITAR allow the user to specify the harvest index and biomass produced by the plant every year. The model will then simulate plant growth to meet these specified values. If you are studying the effect of management practices on yields or you want the biomass to vary in response to different weather conditions, you would not want to use HITAR or BIO_TARG.
ALAINIT	Initial leaf area index (optional). This variable would be used only for covers/plants which are transplanted rather than established from seeds.

Variable name	Definition
BIO_INIT	Initial dry weight biomass (kg/ha) (optional). This variable would be used only for covers/plants that are transplanted rather than established from seeds.
CNOP	SCS runoff curve number for moisture condition II (optional). The initial curve number for the HRU is input in the second line of the .mgt file. If you wish to use one moisture condition II curve number for the entire year, place that value in the second line of the .mgt file and do not enter values for CNOP in the operation lines. If you want the moisture condition II value to vary through the year, management operations 1, 5, and 6 allow new runoff curve numbers to be entered. The curve number value for CNOP should be for pervious ground. In HRUs with urban areas, the model will adjust the curve number to reflect the impact of the impervious areas.

The format of the planting operation line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
HEAT UNITS	space 21-28	decimal (xxxx.xxx)	f8.3
NCR	space 29-32	4-digit integer	i4
HITAR	space 33-40	decimal (xxxx.xxx)	f8.3
BIO_TARG	space 41-48	decimal (xxxx.xxx)	f8.3
ALAINIT	space 49-56	decimal (xxxx.xxx)	f8.3
BIO_INIT	space 61-66	decimal (xx.xxx)	f6.3
CNOP	space 67-72	decimal (xx.xxx)	f6.3

37.1.2.2 IRRIGATION OPERATION

The variables which may be entered on the irrigation line are listed and described below

Variable name	Definition
MONTH	Month operation takes place.
DAY	Day operation takes place.
HUSC	Fraction of total heat units for the year at which operation takes place. (If MONTH and DAY are not provided, HUSC must be set to a value)
MGT_OP	Management operation number. MGT_OP = 2 for irrigation operation
IRR_AMT	Depth of irrigation water applied on HRU (mm).
IRR_SALT	Concentration of salt in irrigation water (mg/L) (optional). *not currently active*

The format of the irrigation operation line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
IRR_AMT	space 33-40	decimal (xxxx.xxx)	f8.3
IRR_SALT	space 41-48	decimal (xxxx.xxx)	f8.3

37.1.2.3 FERTILIZER APPLICATION

The variables which may be entered on the fertilization line are listed and described below

Variable name	Definition
MONTH	Month operation takes place.
DAY	Day operation takes place.
HUSC	Fraction of total heat units for the year at which operation takes place. (If MONTH and DAY are not provided, HUSC must be set to a value)
MGT_OP	Management operation number. MGT_OP = 3 for fertilizer application
FRT_LY1	Fraction of fertilizer applied to top 10mm of soil. The remaining fraction is applied to the 1st soil layer below 10 mm. If FRT_LY1 is set to 0, the model applies 20% of the fertilizer to the top 10mm and the remainder to the 1st soil layer below 10mm.
FERT_ID	Fertilizer identification number. This corresponds to the line number of the fertilizer in fert.dat. If no identification number is provided, the model assumes 28-10-10 is being applied.
FRT_KG	Amount of fertilizer applied to HRU (kg/ha).

The format of the fertilizer application line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
FRY_LY1	space 21-28	decimal (xxxx.xxx)	f8.3
FERT_ID	space 29-32	4-digit integer	i4
FRT_KG	space 33-40	decimal (xxxx.xxx)	f8.3

37.1.2.4 PESTICIDE APPLICATION

The variables which may be entered on the pesticide application line are listed and described below

Variable name	Definition
MONTH	Month operation takes place.
DAY	Day operation takes place.
HUSC	Fraction of total heat units for the year at which operation takes place. (If MONTH and DAY are not provided, HUSC must be set to a value)
MGT_OP	Management operation number. MGT_OP = 4 for pesticide application
PEST_ID	Pesticide identification code from pesticide database (pest.dat).
PST_KG	Amount of pesticide applied to HRU (kg/ha).

The format of the pesticide application line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
PEST_ID	space 57-60	4-digit integer	i4
PST_KG	space 61-66	decimal (xx.xxx)	f6.3

37.1.2.5 HARVEST AND KILL OPERATION

The variables which may be entered on the harvest and kill line are listed and described below

Variable name	Definition
MONTH	Month operation takes place.
DAY	Day operation takes place.
HUSC	Fraction of total heat units for the year at which operation takes place. (If MONTH and DAY are not provided, HUSC must be set to a value)
MGT_OP	Management operation number. MGT_OP = 5 for harvest and kill operation
CNOP	SCS runoff curve number for moisture condition II (optional). The initial curve number for the HRU is input in the second line of the .mgt file. If you wish to use one moisture condition II curve number for the entire year, place that value in the second line of the .mgt file and do not enter values for CNOP in the operation lines. If you want the moisture condition II value to vary through the year, management operations 1, 5, and 6 allow new runoff curve numbers to be entered. The curve number value for CNOP should be for pervious ground. In HRUs with urban areas, the model will adjust the curve number to reflect the impact of the impervious areas.

The format of the harvest and kill line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
CNOP	space 67-72	decimal (xx.xxx)	f6.3

37.1.2.6 TILLAGE OPERATION

The variables which may be entered on the tillage line are listed and described below

Variable name	Definition
MONTH	Month operation takes place.
DAY	Day operation takes place.
HUSC	Fraction of total heat units for the year at which operation takes place. (If MONTH and DAY are not provided, HUSC must be set to a value)
MGT_OP	Management operation number. MGT_OP = 6 for tillage operation
TILLAGE_ID	Tillage implement code from till.dat
CNOP	SCS runoff curve number for moisture condition II (optional). The initial curve number for the HRU is input in the second line of the .mgt file. If you wish to use one moisture condition II curve number for the entire year, place that value in the second line of the .mgt file and do not enter values for CNOP in the operation lines. If you want the moisture condition II value to vary through the year, management operations 1, 5, and 6 allow new runoff curve numbers to be entered. The curve number value for CNOP should be for pervious ground. In HRUs with urban areas, the model will adjust the curve number to reflect the impact of the impervious areas.

The format of the tillage operation line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
TILLAGE_ID	space 29-32	4-digit integer	i4
CNOP	space 67-72	decimal (xx.xxx)	f6.3

37.1.2.7 HARVEST OPERATION

The variables which may be entered on the harvest line are listed and described below

Variable name	Definition
MONTH	Month operation takes place.
DAY	Day operation takes place.
HUSC	Fraction of total heat units for the year at which operation takes place. (If MONTH and DAY are not provided, HUSC must be set to a value)
MGT_OP	Management operation number. MGT_OP = 7 for the harvest only operation
HIOVR	Harvest index override ((kg/ha)/(kg/ha)) Optional. This variable will force the ratio of yield to total aboveground biomass to the specified value. The harvest index in the plant growth database (crop.dat) assumes only the seed is being harvested. If biomass is cut and removed (for example, in hay cuttings), HIOVR must be used to specify the amount of biomass removed.
HARVEFF	Harvest efficiency. Optional. This variable defines the efficiency of the harvest operation and is set to a value between 0.0 and 1.0. If the efficiency is set to a value less than 1.0 the fraction of biomass or yield removed is the fraction defined by the harvest efficiency. The remainder is converted to residue. If no value is defined for HARVEFF, the model assumes all of the biomass/yield is removed.

The format of the harvest operation line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
HIOVR	space 21-28	decimal (xxxx.xxx)	f8.3
HARVEFF	space 33-40	decimal (xxxx.xxx)	f8.3

37.1.2.8 KILL OPERATION

The variables which may be entered on the kill line are listed and described below

Variable name	Definition
MONTH	Month operation takes place.
DAY	Day operation takes place.
HUSC	Fraction of total heat units for the year at which operation takes place. (If MONTH and DAY are not provided, HUSC must be set to a value)
MGT_OP	Management operation number. MGT_OP = 8 for kill operation

The format of the kill line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4

37.1.2.9 GRAZING OPERATION

The variables which may be entered on the grazing line are listed and described below

Variable name	Definition
MONTH	Month grazing begins.
DAY	Day grazing begins.
HUSC	Fraction of total heat units for the year at which grazing begins. (If MONTH and DAY are not provided, HUSC must be set to a value)
MGT_OP	Management operation number. MGT_OP = 9 for grazing operation
BMEAT	Dry weight of biomass consumed daily ((kg/ha)/day).
NDGRAZ	Number of consecutive days grazing takes place in the HRU.
BMTRMP	Dry weight of biomass trampled daily ((kg/ha)/day) (optional). Trampling becomes significant as the number of animals grazed per hectare increases. This is a very subjective value which is typically set equal to BMEAT, i.e. the animals trample as much as they eat.
WMANURE	Dry weight of manure deposited daily ((kg/ha)/day).
IGFTYP	Manure identification code from fert.dat.

The format of the grazing operation line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
BMEAT	space 21-28	decimal (xxxx.xxx)	f8.3
NDGRAZ	space 29-32	4-digit integer	i4
BMTRMP	space 33-40	decimal (xxxx.xxx)	f8.3
WMANURE	space 49-56	decimal (xxxx.xxx)	f8.3
IGFTYP	space 57-60	4-digit integer	i4

37.1.2.10 AUTO IRRIGATION INITIALIZATION

The variables which may be entered on the auto irrigation line are listed and described below

Variable name	Definition
MONTH	Month auto irrigation is initialized.
DAY	Day auto irrigation is initialized.
HUSC	Fraction of total heat units for the year at which auto irrigation is initialized. (If MONTH and DAY are not provided, HUSC must be set to a value)
MGT_OP	Management operation number. MGT_OP = 10 for auto irrigation initialization
AUTO_WSTR	Water stress factor of cover/plant that triggers irrigation. The water stress factor is calculated by dividing the growth of the plant undergoing water stress by the growth of the plant if there was no water stress. This factor ranges from 0.0 to 1.0 where 0.0 indicates there is no growth of the plant due to water stress and 1.0 indicates there is no reduction of plant growth due to water stress.

The format of the auto irrigation line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
AUTO_WSTR	space 33-40	decimal (xxxx.xxx)	f8.3

37.1.2.11 AUTO FERTILIZATION INITIALIZATION

Auto fertilization needs to be initialized only once in the management file. The variables which may be entered on the auto fertilization line are listed and described below.

Variable name	Definition
MONTH	Month initialization takes place.
DAY	Day initialization takes place.
HUSC	Fraction of total heat units for the year at which initialization takes place. (If MONTH and DAY are not provided, HUSC must be set to a value)
MGT_OP	Management operation number. MGT_OP = 11 for auto fertilization initialization
AUTO_NSTR	Nitrogen stress factor of cover/plant that triggers fertilization. The nitrogen stress factor is calculated by dividing the growth of the plant undergoing nitrogen stress by the growth of the plant if there was no nitrogen stress. This factor ranges from 0.0 to 1.0 where 0.0 indicates there is no growth of the plant due to nitrogen stress and 1.0 indicates there is no reduction of plant growth due to nitrogen stress.
FERT_ID	Fertilizer identification number. This corresponds to the line number of the fertilizer in fert.dat. If this variable is left blank or set to zero, the model will apply the commercial fertilizer 28-10-10.
AUTO_NMXS	Maximum amount of mineral N allowed in any one application (kg N/ha). If this variable is left blank, the model will set AUTO_NMXS = 200.
AUTO_NMXA	Maximum amount of mineral N allowed to be applied in any one year (kg N/ha). If this variable is left blank, the model will set AUTO_NMXA = 300.

Variable name	Definition
AUTO_EFF	Application efficiency. The amount of fertilizer applied in auto fertilization is based on the amount of nitrogen removed at harvest. If you set AUTO_EFF = 1.0, the model will apply enough fertilizer to replace the amount of nitrogen removed at harvest. If AUTO_EFF > 1.0, the model will apply fertilizer to meet harvest removal plus an extra amount to make up for nitrogen losses due to surface runoff/leaching. If AUTO_EFF < 1.0, the model will apply fertilizer at the specified fraction below the amount removed at harvest. If this variable is left blank, the model will set AUTO_EFF = 1.3.
AFRT_LY1	Fraction of fertilizer applied to top 10mm of soil. The remaining fraction is applied to the 1st soil layer below 10mm. If this variable is left blank, the model will set AFRT_LY1 = 0.2.

The format of the auto fertilization line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
AUTO_NSTR	space 21-28	decimal (xxxx.xxx)	f8.3
FERT_ID	space 29-32	4-digit integer	i4
AUTO_NMXS	space 33-40	decimal (xxxx.xxx)	f8.3
AUTO_NMXA	space 41-48	decimal (xxxx.xxx)	f8.3
AUTO_EFF	space 61-66	decimal (xx.xxx)	f6.3
AFRT_LY1	space 67-72	decimal (xx.xxx)	f6.3

37.1.2.12 STREET SWEEPING OPERATION

The street sweeping operation can be used only if the urban build up/wash off routines have been selected for the HRU. The variables which may be entered on the street sweeping line are listed and described below.

Variable name	Definition
MONTH	Month operation takes place.
DAY	Day operation takes place.
HUSC	Fraction of heat units at which street sweeping takes place. (If MONTH and DAY are not provided, HUSC must be set to a value)
MGT_OP	Management operation number. MGT_OP = 12 for street sweeping
SWEEPEFF	Removal efficiency of sweeping operation. SWEEPEFF is a fraction that ranges between 0.0 and 1.0. A value of 0.0 indicates that none of the built-up sediments are removed while a value of 1.0 indicates that all of the built-up sediments are removed.
AVWSP	Fraction of curb length available for sweeping. The amount of curb length available for sweeping may be less than the total length due to the presence of parked cars and other obstructions. AVWSP can range from 0.01 to 1.00. If no value is entered for AVWSP (AVWSP left blank or set to 0.0, the model will assume 100% of the curb length is available for sweeping.

The format of the street sweeping line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
SWEEPEFF	space 21-28	decimal (xxxx.xxx)	f8.3
AVWSP	space 33-40	decimal (xxxx.xxx)	f8.3

37.1.2.13 RELEASE/IMPOUND OPERATION

The release/impound operation can be used only in the HRU designated as a depressional/impounded area in the subbasin (IPOT in .hru). The variables which may be entered on the release/impound line are listed and described below.

Variable name	Definition
MONTH	Month operation takes place.
DAY	Day operation takes place.
HUSC	Fraction of total heat units at which release/impounding takes place. (If MONTH and DAY are not provided, HUSC must be set to a value)
MGT_OP	Management operation number. MGT_OP = 13 for release/impoundment of water
IREL_IMP	Release/impound action code: 0 initiate water impoundment 1 initiate water release

The format of the release/impound line is

Variable name	Position	Format	F90 Format
MONTH	space 1-4	4-digit integer	i4
DAY	space 5-8	4-digit integer	i4
HUSC	space 9-16	decimal (xxxx.xxx)	f8.3
MGT_OP	space 17-20	4-digit integer	i4
IREL_IMP	space 29-32	4-digit integer	i4

37.1.2.14 END OF YEAR OPERATION

SWAT requires a blank line to be inserted after all operations for a single year are listed. The blank line lets the model know that there will be no more operations in the year.

If a rotation is being simulated in which the land is left fallow for one of the years with no operations occurring, a blank line should be entered for the fallow year.

37.2 WATER USE INPUT FILE (.WUS)

The water use file quantifies consumptive water use in the watershed. The water removed is considered to be lost from the system. This file is used to simulate removal of water for irrigation outside the watershed or removal of water for urban/industrial use.

Following is a brief description of the variables in the water use input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first three lines of the .wus file are reserved for user comments. The comments may take up to 80 spaces on each line. (optional)
WUPND(mon)	Average daily water removal from the pond for the month (10^4 m^3/day). (optional)
WURCH(mon)	Average daily water removal from the reach for the month (10^4 m^3/day). (optional)
WUSHAL(mon)	Average daily water removal from the shallow aquifer for the month (10^4 m^3/day). (optional)
WUDEEP(mon)	Average daily water removal from the deep aquifer for the month (10^4 m^3/day). (optional)

The format of the water use file is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1-3	space 1-80	character	a80
WUPND(1)	4	space 1-10	decimal (xxxxxxxx.x)	f10.1
WUPND(2)	4	space 11-20	decimal (xxxxxxxx.x)	f10.1
WUPND(3)	4	space 21-30	decimal (xxxxxxxx.x)	f10.1
WUPND(4:)	4	space 31-40	decimal (xxxxxxxx.x)	f10.1
WUPND(5)	4	space 41-50	decimal (xxxxxxxx.x)	f10.1
WUPND(6)	4	space 51-60	decimal (xxxxxxxx.x)	f10.1

Variable name	Line #	Position	Format	F90 Format
WUPND(7)	5	space 1-10	decimal (xxxxxxxx.x)	f10.1
WUPND(8)	5	space 11-20	decimal (xxxxxxxx.x)	f10.1
WUPND(9)	5	space 21-30	decimal (xxxxxxxx.x)	f10.1
WUPND(10)	5	space 31-40	decimal (xxxxxxxx.x)	f10.1
WUPND(11)	5	space 41-50	decimal (xxxxxxxx.x)	f10.1
WUPND(12)	5	space 51-60	decimal (xxxxxxxx.x)	f10.1
WURCH(1)	6	space 1-10	decimal (xxxxxxxx.x)	f10.1
WURCH(2)	6	space 11-20	decimal (xxxxxxxx.x)	f10.1
WURCH(3)	6	space 21-30	decimal (xxxxxxxx.x)	f10.1
WURCH(4)	6	space 31-40	decimal (xxxxxxxx.x)	f10.1
WURCH(5)	6	space 41-50	decimal (xxxxxxxx.x)	f10.1
WURCH(6)	6	space 51-60	decimal (xxxxxxxx.x)	f10.1
WURCH(7)	7	space 1-10	decimal (xxxxxxxx.x)	f10.1
WURCH(8)	7	space 11-20	decimal (xxxxxxxx.x)	f10.1
WURCH(9)	7	space 21-30	decimal (xxxxxxxx.x)	f10.1
WURCH(10)	7	space 31-40	decimal (xxxxxxxx.x)	f10.1
WURCH(11)	7	space 41-50	decimal (xxxxxxxx.x)	f10.1
WURCH(12)	7	space 51-60	decimal (xxxxxxxx.x)	f10.1
WUSHAL(1)	8	space 1-10	decimal (xxxxxxxx.x)	f10.1
WUSHAL(2)	8	space 11-20	decimal (xxxxxxxx.x)	f10.1
WUSHAL(3)	8	space 21-30	decimal (xxxxxxxx.x)	f10.1
WUSHAL(4)	8	space 31-40	decimal (xxxxxxxx.x)	f10.1
WUSHAL(5)	8	space 41-50	decimal (xxxxxxxx.x)	f10.1
WUSHAL(6)	8	space 51-60	decimal (xxxxxxxx.x)	f10.1
WUSHAL(7)	9	space 1-10	decimal (xxxxxxxx.x)	f10.1
WUSHAL(8)	9	space 11-20	decimal (xxxxxxxx.x)	f10.1
WUSHAL(9)	9	space 21-30	decimal (xxxxxxxx.x)	f10.1
WUSHAL(10)	9	space 31-40	decimal (xxxxxxxx.x)	f10.1
WUSHAL(11)	9	space 41-50	decimal (xxxxxxxx.x)	f10.1
WUSHAL(12)	9	space 51-60	decimal (xxxxxxxx.x)	f10.1
WUDEEP(1)	10	space 1-10	decimal (xxxxxxxx.x)	f10.1
WUDEEP(2)	10	space 11-20	decimal (xxxxxxxx.x)	f10.1
WUDEEP(3)	10	space 21-30	decimal (xxxxxxxx.x)	f10.1
WUDEEP(4)	10	space 31-40	decimal (xxxxxxxx.x)	f10.1

Variable name	Line #	Position	Format	F90 Format
WUDEEP(5)	10	space 41-50	decimal (xxxxxxxx.x)	f10.1
WUDEEP(6)	10	space 51-60	decimal (xxxxxxxx.x)	f10.1
WUDEEP(7)	11	space 1-10	decimal (xxxxxxxx.x)	f10.1
WUDEEP(8)	11	space 11-20	decimal (xxxxxxxx.x)	f10.1
WUDEEP(9)	11	space 21-30	decimal (xxxxxxxx.x)	f10.1
WUDEEP(10)	11	space 31-40	decimal (xxxxxxxx.x)	f10.1
WUDEEP(11)	11	space 41-50	decimal (xxxxxxxx.x)	f10.1
WUDEEP(12)	11	space 51-60	decimal (xxxxxxxx.x)	f10.1

CHAPTER 38

SWAT INPUT DATA: GROUNDWATER

SWAT partitions groundwater into two aquifer systems: a shallow, unconfined aquifer which contributes return flow to streams within the watershed and a deep, confined aquifer which contributes return flow to streams outside the watershed. The properties governing water movement into and out of the aquifers are initialized in the groundwater input file.

38.1 GROUNDWATER INPUT FILE (.GW)

Following is a brief description of the variables in the groundwater input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the .gw file is reserved for user comments. The comments may take up to 80 spaces. (optional)
SHALLST	Initial depth of water in the shallow aquifer (mm H_2O).
DEEPST	Initial depth of water in the deep aquifer (mm H_2O). If no value for DEEPST is entered, the model sets DEEPST = 1000.0.
GW_DELAY	Groundwater delay (days). The time required for water leaving the bottom of the root zone to reach the shallow aquifer.
ALPHA_BF	Baseflow alpha factor (days). The baseflow alpha factor, or recession constant, characterizes the groundwater recession curve. This constant will be some number less than 1.0, and will be large (approach one) for flat recessions and small (approach zero) for steep recessions.
GWQMN	Threshold depth of water in the shallow aquifer required for return flow to occur (mm H_2O). Groundwater flow to the reach is allowed only if the depth of water in the shallow aquifer is equal to or greater than GWQMN.
GW_REVAP	Groundwater "revap" coefficient. This variable controls the amount of water which will move from the shallow aquifer to the root zone as a result of soil moisture depletion and the amount of direct water uptake from deep rooted trees and shrubs. As GW_REVAP approaches 0, movement of water from the shallow aquifer to the root zone is restricted. As GW_REVAP approaches 1, the rate of transfer from the shallow aquifer to the root zone approaches the rate of potential evapotranspiration. The value for GW_REVAP should be between 0.02 and 0.20.

Variable name	Definition
REVAPMN	Threshold depth of water in the shallow aquifer for "revap" or percolation to the deep aquifer to occur (mm H_2O). Movement of water from the shallow aquifer to the unsaturated zone or to the deep aquifer is allowed only if the volume of water in the shallow aquifer is equal to or greater than REVAPMN.
RCHRG_DP	Deep aquifer percolation fraction. The fraction of percolation from the root zone which recharges the deep aquifer. The value for RCHRG_DP should be between 0.0 and 1.0.
GWHT	Initial groundwater height (m). Optional.
GW_SPYLD	Specific yield of the shallow aquifer (m^3/m^3). Specific yield is defined as the ratio of the volume of water that drains by gravity to the total volume of rock. Optional.
GWNO3	Concentration of nitrate in groundwater contribution to streamflow from subbasin (mg N/L). Optional.
GWSOLP	Concentration of soluble phosphorus in groundwater contribution to streamflow from subbasin (mg P/L). Optional.

The groundwater file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line.

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
SHALLST	2	real	free
DEEPST	3	real	free
GW_DELAY	4	real	free
ALPHA_BF	5	real	free
GWQMN	6	real	free
GW_REVAP	7	real	free
REVAPMN	8	real	free
RCHRG_DP	9	real	free
GWHT	10	real	free
GW_SPYLD	11	real	free

Variable name	Line #	Format	F90 Format
GWNO3	12	real	free
GWSOLP	13	real	free

CHAPTER 39

SWAT INPUT DATA: MAIN CHANNEL

In order to simulate the physical processes affecting the flow of water and transport of sediment in the channel network of the watershed, SWAT requires information on the physical characteristics of the main channel within each subbasin.

The main channel input file (.rte) summarizes the physical characteristics of the channel which affect water flow and sediment and pesticide transport.

39.1 MAIN CHANNEL INPUT FILE (.RTE)

Following is a brief description of the variables in the main channel input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the .rte file is reserved for user comments. The comments may take up to 80 spaces. (optional)
CH_W(2)	Average width of main channel at top of bank (m).
CH_D	Depth of main channel from top of bank to bottom (m).
CH_S(2)	Average slope of main channel along the channel length (m/m).
CH_L(2)	Length of main channel (km). If no value for CH_L is entered, the model will set CH_L = 0.001.
CH_N(2)	Manning's "n" value for the main channel.
CH_K(2)	Effective hydraulic conductivity in main channel alluvium (mm/hr).
CH_EROD	Channel erodibility factor. CH_EROD is set to a value between 0.0 and 1.0. A value of 0.0 indicates a non-erosive channel while a value of 1.0 indicates no resistance to erosion.
CH_COV	Channel cover factor. CH_COV is set to a value between 0.0 and 1.0. A value of 0.0 indicates that the channel is completely protected from degradation by cover while a value of 1.0 indicates there is no vegetative cover on the channel.
CH_WDR	Channel width-depth ratio (m/m). Required only if channel degradation is being modeled (IDEG = 1 in .cod).
ALPHA_BNK	Baseflow alpha factor for bank storage (days). The baseflow alpha factor, or recession constant, characterizes the bank storage recession curve. This constant will be some number less than 1.0, and will be large (approach one) for flat recessions and small (approach zero) for steep recessions. If no value is entered for ALPHA_BNK, the variable will be set to the same value as ALPHA_BF from the groundwater (.gw) file.

The main channel file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the main channel input file is:

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
CH_W(2)	2	real	free
CH_D	3	real	free
CH_S(2)	4	real	free
CH_L(2)	5	real	free
CH_N(2)	6	real	free
CH_K(2)	7	real	free
CH_EROD	8	real	free
CH_COV	9	real	free
CH_WDR	10	real	free
ALPHA_BNK	11	real	free

CHAPTER 40

SWAT INPUT DATA: RESERVOIRS/PONDS

Impoundment structures modify the movement of water in the channel network by lowering the peak flow and volume of flood discharges. Because impoundments slow down the flow of water, sediment will fall from suspension, removing nutrient and chemicals adsorbed to the soil particles.

SWAT is able to model three types of impoundments. The first type is a small structure with one spillway. Releases occur only when the storage volume of the structure is exceeded and the excess volume is released within one day. The second type of impoundment is a small, uncontrolled reservoir with a principal and emergency spillway. Water is released at a specified rate when the volume of the reservoir exceeds the principal spillway volume. Volume exceeding the emergency spillway storage is released within one day. The third type of impoundment is a managed reservoir. Water may be released from the managed reservoir based on measured outflow or target reservoir volumes. The features of an impoundment are shown in Figure 40.1.

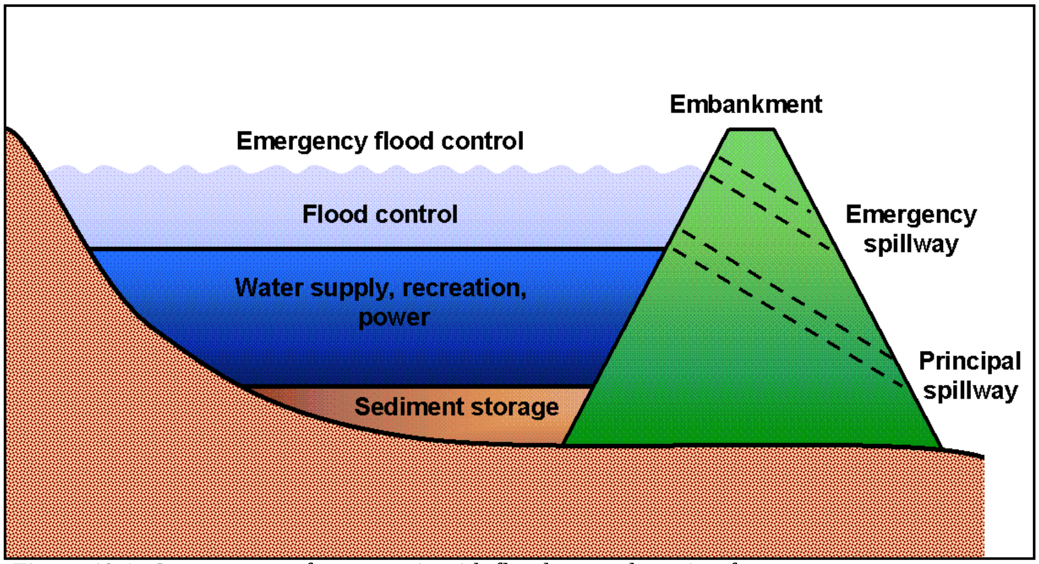


Figure 40.1: Components of a reservoir with flood water detention features.

SWAT uses two files to store information on impoundments, the reservoir input file (.res) and the pond input file (.pnd). An unlimited number of reservoirs may be modeled in a watershed, while a pond may be modeling in each subbasin.

Originally, the pond input file contained data for simple impoundment structures with only one spillway while data for the more complex impoundments was stored in the reservoir input file. Due to user needs, the options allowed for impoundments directly linked to subbasins have been increased over the years and the distinction between "reservoirs" and "ponds" as simulated by SWAT has become somewhat blurred. The key difference between the two structures is that a reservoir is located on the main channel network of the watershed while a pond is located off of the main channel within a subbasin. Consequently, water contribution from a pond is limited to the water loading generated within a subbasin. The following table has been prepared to assist the user in identifying the input file and required variables to be used for different situations. The structures are identified on the basis of how water is released.

Structure to be modeled: impoundment with one spillway where water is released when the storage capacity is exceeded. There is no control on the rate of water release from the impoundment. **File:** .pnd **Additional comments:** values are entered for the principal spillway only—no data should be entered for the emergency spillway (PND_ESA, PND_EVOL) or target storage (IFLOD1, IFLOD2, NDTARG).
Structure to be modeled: small, uncontrolled reservoir with a principal and emergency spillway where water release is passive (e.g. gravity driven). Water is not released until the level stored in the reservoir is above the height of the principal spillway. If the water level is above the principal spillway, water is released at a known rate. If the level of the reservoir rises above the emergency spillway, the volume of water exceeding the storage capacity of the emergency spillway is released within a day. **File:** .res **Additional comments:** the variable IRESCO should be set to 0 and the data required for this option entered.
Structure to be modeled: large, managed reservoir where the daily or monthly values for outflow are known. **File:** .res **Additional comments:** the variable IRESCO should be set to 1 or 3 depending on the outflow data available.
Structure to be modeled: a reservoir which is managed to maintain a certain volume of water (the target storage) at all times **File:** .pnd or .res **Additional comments:** In the .pnd file, the target storage is calculated by the model. The target storage varies between the principal and emergency storage as a function of the time of year—the target storage approaches the principal spillway storage in the flood season while during the non-flood season it approaches the emergency spillway storage. In the .res file, the user specifies the target storage for each month of the year. To use target storage in the .pnd file, values must be entered for PND_ESA, PND_EVOL, IFLOD1, IFLOD2 and NDTARG. To use target storage in the .res file, IRESCO is set to 2 and the data required for this option is entered.

40.1 RESERVOIR INPUT FILE (.RES)

Following is a brief description of the variables in the reservoir input file. They are listed in the order they appear within the file.

Variable name	**Definition**
TITLE	The first line of the file is reserved for user comments. The comments may take up to 80 spaces. (optional)
RES_SUB	Number of the subbasin the reservoir is in (weather for subbasin is used for the reservoir). If no subbasin number is assigned to RES_SUB, the model uses weather data from subbasin 1 to model climatic processes on the reservoir.
MORES	Month the reservoir became operational (1-12). If 0 is input for MORES and IYRES, the model assumes the reservoir is in operation at the beginning of the simulation.
IYRES	Year of the simulation the reservoir became operational (eg 1980). If 0 is input for MORES and IYRES, the model assumes the reservoir is in operation at the beginning of the simulation.
RES_ESA	Reservoir surface area when the reservoir is filled to the emergency spillway (ha)
RES_EVOL	Volume of water needed to fill the reservoir to the emergency spillway (10^4 m^3).
RES_PSA	Reservoir surface area when the reservoir is filled to the principal spillway (ha).
RES_PVOL	Volume of water needed to fill the reservoir to the principal spillway (10^4 m^3).
RES_VOL	Initial reservoir volume. If the reservoir is in existence at the beginning of the simulation period, the initial reservoir volume is the volume on the first day of simulation. If the reservoir begins operation in the midst of a SWAT simulation, the initial reservoir volume is the volume of the reservoir the day the reservoir becomes operational (10^4 m^3).
RES_SED	Initial sediment concentration in the reservoir (mg/L).
RES_NSED	Normal sediment concentration in the reservoir (mg/L).

Variable name	Definition
RES_K	Hydraulic conductivity of the reservoir bottom (mm/hr).
IRESCO	Outflow simulation code: 0 compute outflow for uncontrolled reservoir with average annual release rate (if IRESCO=0, need RES_RR) 1 measured monthly outflow (if IRESCO=1, need RESOUT) 2 simulated controlled outflow—target release (if IRESCO=2, need STARG, IFLOD1R, IFLOD2D, and NDTARGR 3 measured daily outflow (if IRESCO=3, need RESDAYO)
OFLOWMX(mon)	Maximum daily outflow for the month (m^3/s). Set all months to zero if you do not want to trigger this requirement.
OFLOWMN(mon)	Minimum daily outflow for the month (m^3/s). Set all months to zero if you do not want to trigger this requirement.
RES_RR	Average daily principal spillway release rate (m^3/s). Needed if IRESCO = 0.
RESMONO	Name of monthly reservoir outflow file. Required if IRESCO = 1.
IFLOD1R	Beginning month of non-flood season. Needed if IRESCO = 2.
IFLOD2R	Ending month of non-flood season. Needed if IRESCO = 2.
NDTARGR	Number of days to reach target storage from current reservoir storage. Needed if IRESCO = 2.
STARG(mon)	Monthly target reservoir storage (10^4 m^3). Needed if IRESCO = 2.
RESDAYO	Name of daily reservoir outflow file. Required if IRESCO = 3.
WURESN(mon,:)	Average amount of water withdrawn from reservoir each day in the month for consumptive use (10^4 m^3). This variable allows water to be removed from the reservoir for use outside the watershed. (optional)

Variable name	Definition
WURTNF(:)	Fraction of water removed from the reservoir via WURESN that is returned and becomes flow out of reservoir (m^3/m^3). (optional)

The reservoir file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the reservoir input file is:

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
RES_SUB	2	integer	free
MORES	3	integer	free
IYRES	4	integer	free
RES_ESA	5	real	free
RES_EVOL	6	real	free
RES_PSA	7	real	free
RES_PVOL	8	real	free
RES_VOL	9	real	free
RES_SED	10	real	free
RES_NSED	11	real	free
RES_K	12	real	free
IRESCO	13	integer	free
COMMENT LINE	14	character	a80
OFLOWMX(1)	15	real	free
OFLOWMX(2)	15	real	free
OFLOWMX(3)	15	real	free
OFLOWMX(4)	15	real	free
OFLOWMX(5)	15	real	free
OFLOWMX(6)	15	real	free
COMMENT LINE	16	character	a80
OFLOWMX(7)	17	real	free
OFLOWMX(8)	17	real	free
OFLOWMX(9)	17	real	free
OFLOWMX(10)	17	real	free
OFLOWMX(11)	17	real	free

Variable name	Line #	Format	F90 Format
OFLOWMX(12)	17	real	free
COMMENT LINE	18	character	a80
OFLOWMN(1)	19	real	free
OFLOWMN(2)	19	real	free
OFLOWMN(3)	19	real	free
OFLOWMN(4)	19	real	free
OFLOWMN(5)	19	real	free
OFLOWMN(6)	19	real	free
COMMENT LINE	20	character	a80
OFLOWMN(7)	21	real	free
OFLOWMN(8)	21	real	free
OFLOWMN(9)	21	real	free
OFLOWMN(10)	21	real	free
OFLOWMN(11)	21	real	free
OFLOWMN(12)	21	real	free
RES_RR	22	real	free
RESMONO	23	character (len=13)	a13
IFLOD1R	24	integer	free
IFLOD2R	25	integer	free
NDTARGR	26	integer	free
COMMENT LINE	27	character	a80
STARG(1)	28	real	free
STARG(2)	28	real	free
STARG(3)	28	real	free
STARG(4)	28	real	free
STARG(5)	28	real	free
STARG(6)	28	real	free
COMMENT LINE	29	character	a80
STARG(7)	30	real	free
STARG(8)	30	real	free
STARG(9)	30	real	free
STARG(10)	30	real	free
STARG(11)	30	real	free
STARG(12)	30	real	free
RESDAYO	31	character (len=13)	a13

Variable name	Line #	Format	F90 Format
COMMENT LINE	32	character	a80
WURESN(1)	33	real	free
WURESN(2)	33	real	free
WURESN(3)	33	real	free
WURESN(4)	33	real	free
WURESN(5)	33	real	free
WURESN(6)	33	real	free
COMMENT LINE	34	character	a80
WURESN(7)	35	real	free
WURESN(8)	35	real	free
WURESN(9)	35	real	free
WURESN(10)	35	real	free
WURESN(11)	35	real	free
WURESN(12)	35	real	free
WURTNF	36	real	free

40.2 DAILY RESERVOIR OUTFLOW FILE

When measured daily outflow is used for a reservoir, the name of the file containing the data is assigned to the variable RESDAYO. The daily outflow file contains the flow rate for every day of operation of the reservoir, beginning with the first day of operation in the simulation. The daily outflow file contains one variable:

Variable name	Definition
TITLE	The first line of the file is reserved for a description. The description may take up to 80 spaces. (optional)
RES_OUTFLOW	The water release rate for the day (m^3/sec).

The format of the daily reservoir outflow file is:

Variable name	Line #	Position	Format	F90 Format
TITLE	1	space 1-80	character	a80
RES_OUTFLOW	2-END	space 1-8	decimal(xxxxx.xx)	f8.2

40.3 MONTHLY RESERVOIR OUTFLOW FILE

When outflow data average over a month is used for a reservoir, the name of the file containing the data is assigned to the variable RESMONO. The monthly outflow file contains the average daily flow rate for every month of operation of the reservoir, beginning with the first month of operation in the simulation. The monthly outflow file contains the following variables:

Variable name	Definition
TITLE	The first line of the file is reserved for a description. The description may take up to 80 spaces. (optional)
RESOUT(mon,yr)	Measured average daily outflow from the reservoir for the month (m^3/s). Needed when IRESCO = 1. There must be a line of input for every year of simulation.

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
If IRESCO = 1, the model will read the input data for RESOUT. There should be one line for data for RESOUT for each year of simulation beginning with the 1st year of simulation.			
RESOUT(1,yr)	2-END	real	free
RESOUT(2,yr)	2-END	real	free
RESOUT(3,yr)	2-END	real	free
RESOUT(4,yr)	2-END	real	free
RESOUT(5,yr)	2-END	real	free
RESOUT(6,yr)	2-END	real	free
RESOUT(7,yr)	2-END	real	free
RESOUT(8,yr)	2-END	real	free
RESOUT(9,yr)	2-END	real	free
RESOUT(10,yr)	2-END	real	free
RESOUT(11,yr)	2-END	real	free
RESOUT(12,yr)	2-END	real	free

40.4 POND INPUT FILE (.PND)

Following is a brief description of the variables in the subbasin pond input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line of the file is reserved for user comments. The comments may take up to 80 spaces. Optional.
POND SECTION TITLE	The second line of the file is reserved for a section title for the pond data. The model does not process this line. The title may take up to 80 spaces. Optional.
PND_FR	Fraction of subbasin area that drains into ponds. The value for PND_FR should be between 0.0 and 1.0.
PND_PSA	Surface area of ponds when filled to principal spillway (ha).
PND_PVOL	Volume of water stored in ponds when filled to the principal spillway (10^4 m^3 H_2O).
PND_ESA	Surface area of ponds when filled to emergency spillway (ha). Optional.
PND_EVOL	Volume of water stored in ponds when filled to the emergency spillway (10^4 m^3 H_2O). Optional.
PND_VOL	Initial volume of water in ponds (10^4 m^3 H_2O).
PND_SED	Initial sediment concentration in pond water (mg/L).
PND_NSED	Normal sediment concentration in pond water (mg/L).
PND_K	Hydraulic conductivity through bottom of ponds (mm/hr).
IFLOD1	Beginning month of non-flood season. Optional.
IFLOD2	Ending month of non-flood season. Optional.
NDTARG	Number of days needed to reach target storage from current pond storage. The default value for NDTARG is 15 days. Optional.
PSETL1	Phosphorus settling rate in pond for months IPND1 through IPND2 (m/year). Optional.
PSETL2	Phosphorus settling rate in pond for months other than IPND1-IPND2 (m/year). Optional.

Variable name	Definition
NSETL1	Nitrogen settling rate in pond for months IPND1 through IPND2 (m/year). Optional.
NSETL2	Nitrogen settling rate in pond for months other than IPND1-IPND2 (m/year). Optional.
CHLA	Chlorophyll *a* production coefficient for ponds. Chlorophyll *a* concentration in the pond is calculated from the total phosphorus concentration. The equation assumes the system is phosphorus limited. The chlorophyll *a* coefficient was added to the equation to allow the user to adjust results to account for other factors ignored by the basic equation such as nitrogen limitations. The default value for CHLA is 1.00, which uses the original equation. Optional.
SECCI	Water clarity coefficient for ponds. The clarity of the pond is expressed by the secci-disk depth (m) which is calculated as a function of chlorophyll *a*. Because suspended sediment also can affect water clarity, the water clarity coefficient has been added to the equation to allow users to adjust for the impact of factors other than chlorophyll *a* on water clarity. The default value for SECCI is 1.00, which uses the original equation. Optional.
PND_NO3	Initial concentration of NO_3-N in pond (mg N/L). Optional.
PND_SOLP	Initial concentration of soluble P in pond (mg P/L). Optional.
PND_ORGN	Initial concentration of organic N in pond (mg N/L). Optional.
PND_ORGP	Initial concentration of organic P in pond (mg P/L). Optional.
COMMON VARIABLES SECTION TITLE	The 25^{th} line of the file is reserved for a section title for data used for ponds and wetlands. The model does not process this line. The title may take up to 80 spaces. Optional.
IPND1	Beginning month of mid-year nutrient settling “season”. Optional.
IPND2	Ending month of mid-year nutrient settling “season”. Optional.

Variable name	**Definition**
WETLAND SECTION TITLE	The 28^{th} line of the file is reserved for a section title for the wetland data. The model does not process this line. The title may take up to 80 spaces. Optional.
WET_FR	Fraction of subbasin area that drains into wetlands.
WET_NSA	Surface area of wetlands at normal water level (ha).
WET_NVOL	Volume of water stored in wetlands when filled to normal water level (10^4 m^3 H_2O).
WET_MXSA	Surface area of wetlands at maximum water level (ha).
WET_MXVOL	Volume of water stored in wetlands when filled to maximum water level (10^4 m^3 H_2O).
WET_VOL	Initial volume of water in wetlands (10^4 m^3 H_2O).
WET_SED	Initial sediment concentration in wetland water (mg/L).
WET_NSED	Normal sediment concentration in wetland water (mg/L).
WET_K	Hydraulic conductivity of bottom of wetlands (mm/hr).
PSETLW1	Phosphorus settling rate in wetland for months IPND1 through IPND2 (m/year). Optional.
PSETLW2	Phosphorus settling rate in wetlands for months other than IPND1-IPND2 (m/year). Optional.
NSETLW1	Nitrogen settling rate in wetlands for months IPND1 through IPND2 (m/year). Optional.
NSETLW2	Nitrogen settling rate in wetlands for months other than IPND1-IPND2 (m/year). Optional.
CHLAW	Chlorophyll *a* production coefficient for wetlands. Chlorophyll *a* concentration in the wetland is calculated from the total phosphorus concentration. The equation assumes the system is phosphorus limited. The chlorophyll *a* coefficient was added to the equation to allow the user to adjust results to account for other factors ignored by the basic equation such as nitrogen limitations. The default value for CHLA is 1.00, which uses the original equation. Optional.

Variable name	Definition
SECCIW	Water clarity coefficient for wetlands. The clarity of the wetland is expressed by the secci-disk depth (m) which is calculated as a function of chlorophyll *a*. Because suspended sediment also can affect water clarity, the water clarity coefficient has been added to the equation to allow users to adjust for the impact of factors other than chlorophyll *a* on water clarity. The default value for SECCI is 1.00, which uses the original equation. Optional.
WET_NO3	Initial concentration of NO_3-N in wetland (mg N/L). Optional.
WET_SOLP	Initial concentration of soluble P in wetland (mg P/L). Optional.
WET_ORGN	Initial concentration of organic N in wetland (mg N/L). Optional.
WET_ORGP	Initial concentration of organic P in wetland (mg P/L). Optional.

The pond input file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the pond input file is:

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
POND SECT. TITLE	2	character	a80
PND_FR	3	real	free
PND_PSA	4	real	free
PND_PVOL	5	real	free
PND_ESA	6	real	free
PND_EVOL	7	real	free
PND_VOL	8	real	free
PND_SED	9	real	free
PND_NSED	10	real	free
PND_K	11	real	free
IFLOD1	12	integer	free
IFLOD2	13	integer	free

Variable name	Line #	Format	F90 Format
NDTARG	14	integer	free
PSETL1	15	real	free
PSETL2	16	real	free
NSETL1	17	real	free
NSETL2	18	real	free
CHLA	19	real	free
SECCI	20	real	free
PND_NO3	21	real	free
PND_SOLP	22	real	free
PND_ORGN	23	real	free
PND_ORGP	24	real	free
POND/WETLAND SECT. TITLE	25	character	a80
IPND1	26	integer	free
IPND2	27	integer	free
WETLAND SECT. TITLE	28	character	a80
WET_FR	29	real	free
WET_NSA	30	real	free
WET_NVOL	31	real	free
WET_MXSA	32	real	free
WET_MXVOL	33	real	free
WET_VOL	34	real	free
WET_SED	35	real	free
WET_NSED	36	real	free
WET_K	37	real	free
PSETLW1	38	real	free
PSETLW2	39	real	free
NSETLW1	40	real	free
NSETLW2	41	real	free
CHLAW	42	real	free
SECCIW	43	real	free
WET_NO3	44	real	free
WET_SOLP	45	real	free
WET_ORGN	46	real	free
WET_ORGP	47	real	free

CHAPTER **41**

SWAT INPUT DATA: WATER QUALITY

While water quality is a broad subject, the primary areas of concern are nutrients, organic chemicals—both agricultural (pesticide) and industrial, heavy metals, bacteria and sediment levels in streams and large water bodies. SWAT is able to model processes affecting nutrient, pesticide and sediment levels in the main channels and reservoirs. The data used by SWAT for water quality is primarily contained within three files: the stream water quality input file (.swq), the general water quality input file (.wwq), and the lake water quality input file (.lwq).

The stream water quality input file and the general water quality input file contain input data used in the QUAL2E subroutines in the model.

41.1 GENERAL WATER QUALITY INPUT FILE (.WWQ)

The general water quality input file contains information used by SWAT to initialize stream water quality variables that apply to the entire watershed.

Following is a brief description of the variables in the general water quality input file. The variables are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line is reserved for user comments. This line is not processed by the model.
LAO	Qual2E light averaging option. Qual2E defines four light averaging options. 1 Depth-averaged algal growth attenuation factor for light (FL) is computed from one daylight average solar radiation value calculated in the steady state temperature heat balance. 2 FL is computed from one daylight average solar radiation value supplied by the user. 3 FL is obtained by averaging the hourly daylight values of FL computed from the hourly daylight values of solar radiation calculated in the steady state temperature heat balance. 4 FL is obtained by averaging the hourly daylight values of FL computed from the hourly daylight values of solar radiation calculated from a single value of total daily, photosynthetically active, solar radiation and an assumed cosine function. The only option currently active in SWAT is 2.
IGROPT	Qual2E algal specific growth rate option. Qual2E provides three different options for computing the algal growth rate. 1 Multiplicative: the effects of nitrogen, phosphorus and light are multiplied together to calculate the net effect on the local algal growth rate

Variable name	Definition
IGROPT, cont.	2 Limiting nutrient: the local algal growth rate is limited by light and one of the nutrients (nitrogen or phosphorus) 3 Harmonic mean: the local algal growth rate is limited by light and the harmonic mean of the nutrient interactions The default option is the limiting nutrient option (2).
AI0	Ratio of chlorophyll-a to algal biomass (μg-chla/mg algae). Values for AI0 should fall in the range 10-100. If no value for AI0 is entered, the model will set AI0 = 50.0.
AI1	Fraction of algal biomass that is nitrogen (mg N/mg alg). Values for AI1 should fall in the range 0.07-0.09. If no value for AI1 is entered, the model will set AI1 = 0.08.
AI2	Fraction of algal biomass that is phosphorus (mg P/mg alg). Values for AI2 should fall in the range 0.01-0.02. If no value for AI2 is entered, the model will set AI2 = 0.015.
AI3	The rate of oxygen production per unit of algal photosynthesis (mg O_2/mg alg). Values for AI3 should fall in the range 1.4-1.8. If no value for AI3 is entered, the model will set AI3 = 1.6.
AI4	The rate of oxygen uptake per unit of algal respiration (mg O_2/mg alg). Values for AI4 should fall in the range 1.6-2.3. If no value for AI4 is entered, the model will set AI4 = 2.0.
AI5	The rate of oxygen uptake per unit of NH_3-N oxidation (mg O_2/mg NH_3-N). Values for AI5 should fall in the range 3.0-4.0. If no value for AI5 is entered, the model will set AI5 = 3.5.
AI6	The rate of oxygen uptake per unit of NO_2-N oxidation (mg O_2/mg NO_2-N). Values for AI6 should fall in the range 1.00-1.14. If no value for AI6 is entered, the model will set AI6 = 1.07.
MUMAX	Maximum specific algal growth rate at 20º C (day^{-1}). Values for MUMAX should fall in the range 1.0-3.0. If no value for MUMAX is entered, the model will set MUMAX = 2.0.
RHOQ	Algal respiration rate at 20º C (day^{-1}). Values for RHOQ should fall in the range 0.05-0.50. If no value for RHOQ is entered, the model will set RHOQ = 0.30.

Variable name	Definition
TFACT	Fraction of solar radiation computed in the temperature heat balance that is photosynthetically active. Values for TFACT should fall in the range 0.01-1.0. If no value for TFACT is entered, the model will set TFACT = 0.3.
K_L	Half-saturation coefficient for light (kJ/(m^2·min)). Values for K_L should fall in the range 0.2227-1.135. If no value for K_L is entered, the model will set K_L = 0.75.
K_N	Michaelis-Menton half-saturation constant for nitrogen (mg N/L). Values for K_N should fall in the range 0.01-0.30. If no value for K_N is entered, the model will set K_N = 0.02.
K_P	Michaelis-Menton half-saturation constant for phosphorus (mg P/L). Values for K_P should fall in the range 0.001-0.050. If no value for K_P is entered, the model will set K_P = 0.025.
LAMBDA0	Non-algal portion of the light extinction coefficient (m^{-1}). If no value for LAMBDA0 is entered, the model will set LAMBDA0 = 1.0.
LAMBDA1	Linear algal self-shading coefficient (m^{-1}·(µg chla/L)$^{-1}$). Values for LAMBDA1 should fall in the range 0.0065-0.065. If no value for LAMBDA1 is entered, the model will set LAMBDA1 = 0.03.
LAMBDA2	Nonlinear algal self-shading coefficient (m^{-1}·(µg chla/L)$^{-2/3}$). The recommended value for LAMBDA2 is 0.0541. If no value for LAMBDA2 is entered, the model will set LAMBDA2 = 0.054.
P_N	Algal preference factor for ammonia. Values for P_N should fall in the range 0.01-1.0. If no value for P_N is entered, the model will set P_N = 0.5.

The watershed water quality file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the general water quality input file is:

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
LAO	2	integer	free
IGROPT	3	integer	free
AI0	4	real	free
AI1	5	real	free
AI2	6	real	free
AI3	7	real	free
AI4	8	real	free
AI5	9	real	free
AI6	10	real	free
MUMAX	11	real	free
RHOQ	12	real	free
TFACT	13	real	free
K_L	14	real	free
K_N	15	real	free
K_P	16	real	free
LAMBDA0	17	real	free
LAMBDA1	18	real	free
LAMBDA2	19	real	free
P_N	20	real	free

41.2 STREAM WATER QUALITY INPUT FILE (.SWQ)

The stream water quality input file contains information used by SWAT to set main channel water quality attributes in the subbasins.

Following is a brief description of the variables in the stream water quality input file. The variables are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first line is reserved for user comments. This line is not processed by the model.
NUTRIENT TITLE	The second line is reserved for the nutrient section title. This line is not processed by the model.
DISOX	Initial dissolved oxygen concentration in the reach (mg O_2/L). If no value for DISOX is entered, the model sets DISOX = 0.0.
BOD	Initial carbonaceous biochemical oxygen demand in the reach (mg O_2/L). If no value for BOD is entered, the model sets BOD = 0.0.
ALGAE	Initial chlorophyll-a concentration in the reach (mg chl-a/L). If no value for ALGAE is entered, the model sets ALGAE = 0.0.
ORGANICN	Initial organic nitrogen concentration in the reach (mg org N-N/L). If no value for ORGANICN is entered, the model sets ORGANICN = 0.0.
AMMONIAN	Initial ammonia concentration in the reach (mg NH_3-N/L). If no value for AMMONIAN is entered, the model sets AMMONIAN = 0.0.
NITRITEN	Initial nitrite concentration in the reach (mg NO_2-N/L). If no value for NITRITEN is entered, the model sets NITRITEN = 0.0.
NITRATEN	Initial nitrate concentration in the reach (mg NO_3-N/L). If no value for NITRATEN is entered, the model sets NITRATEN = 0.0.

Variable name	Definition
ORGANICP	Initial organic phosphorus concentration in the reach (mg org P-P/L). If no value for ORGANICP is entered, the model sets ORGANICP = 0.0.
DISOLVP	Initial dissolved phosphorus concentration in the reach (mg sol P-P/L). If no value for DISOLVP is entered, the model sets DISOLVP = 0.0.
RS1	Local algal settling rate in the reach at 20º C (m/day). Values for RS1 should fall in the range 0.15 to 1.82. If no value for RS1 is entered, the model sets RS1 = 1.0.
RS2	Benthic (sediment) source rate for dissolved phosphorus in the reach at 20º C (mg dissolved P/(m^2·day)). If no value for RS2 is entered, the model sets RS2 = 0.05.
RS3	Benthic source rate for NH_4-N in the reach at 20º C (mg NH_4-N/(m^2·day)). If no value for RS3 is entered, the model sets RS3 = 0.5.
RS4	Rate coefficient for organic N settling in the reach at 20º C (day^{-1}). Values for RS4 should fall in the range 0.001 to 0.10. If no value for RS4 is entered, the model sets RS4 = 0.05.
RS5	Organic phosphorus settling rate in the reach at 20º C (day^{-1}). Values for RS5 should fall in the range 0.001 to 0.1. If no value for RS5 is entered, the model sets RS5 = 0.05.
RS6	Rate coefficient for settling of arbitrary non-conservative constituent in the reach at 20º C (day^{-1}). If no value for RS6 is entered, the model sets RS6 = 2.5. (*not currently used by the model*)
RS7	Benthic source rate for arbitrary non-conservative constituent in the reach at 20º C (mg ANC/(m^2·day)). If no value for RS7 is entered, the model sets RS7 = 2.5. (*not currently used by the model*)
RK1	Carbonaceous biological oxygen demand deoxygenation rate coefficient in the reach at 20º C (day^{-1}). Values for RK1 should fall in the range 0.02 to 3.4. If no value for RK1 is entered, the model sets RK1 = 1.71.
RK2	Oxygen reaeration rate in accordance with Fickian diffusion in the reach at 20º C (day^{-1}). Values for RK2 should fall in the range 0.01 to 100.0. If no value for RK2 is entered, the model sets RK2 = 50.0.

Variable name	Definition
RK3	Rate of loss of carbonaceous biological oxygen demand due to settling in the reach at 20º C (day^{-1}). Values for RK3 should fall in the range -0.36 to 0.36. The recommended default for RK3 is 0.36 (not set by model).
RK4	Benthic oxygen demand rate in the reach at 20º C (mg $O_2/(m^2 \cdot day)$). If no value for RK4 is entered, the model sets RK4 = 2.0.
RK5	Coliform die-off rate in the reach at 20º C (day^{-1}). Values for RK5 should fall in the range 0.05 to 4.0. If no value for RK5 is entered, the model sets RK5 = 2.0.
RK6	Decay rate for arbitrary non-conservative constituent in the reach at 20º C (day^{-1}). If no value for RK6 is entered, the model sets RK6 = 1.71. (*not currently used by the model*)
BC1	Rate constant for biological oxidation of NH_4 to NO_2 in the reach at 20º C (day^{-1}). Values for BC1 should fall in the range 0.1 to 1.0. If no value for BC1 is entered, the model sets BC1 = 0.55.
BC2	Rate constant for biological oxidation of NO_2 to NO_3 in the reach at 20º C (day^{-1}). Values for BC2 should fall in the range 0.2 to 2.0. If no value for BC2 is entered, the model sets BC2 = 1.1.
BC3	Rate constant for hydrolysis of organic N to NH_4 in the reach at 20º C (day^{-1}). Values for BC3 should fall in the range 0.2 to 0.4. If no value for BC3 is entered, the model sets BC3 = 0.21.
BC4	Rate constant for mineralization of organic P to dissolved P in the reach at 20º C (day^{-1}). Values for BC4 should fall in the range 0.01 to 0.70. If no value for BC4 is entered, the model sets BC4 = 0.35.
PESTICIDE TITLE	This line is reserved for the pesticide section title. This line is not processed by the model.
CHPST_CONC	Initial pesticide concentration in reach (mg/m^3 H_2O). (Optional)
CHPST_REA	Pesticide reaction coefficient in reach (day^{-1}). If no value for CHPST_REA is entered, the model will set CHPST_REA = 0.007. (Optional)

Variable name	Definition
CHPST_VOL	Pesticide volatilization coefficient in reach (m/day). If no value for CHPST_VOL is entered, the model will set CHPST_VOL = 0.01. (Optional)
CHPST_KOC	Pesticide partition coefficient between water and air in reach (m^3/day). If no value for CHPST_KOC is entered, the model will set CHPST_KOC = 0. (Optional)
CHPST_STL	Settling velocity for pesticide sorbed to sediment (m/day). If no value for CHPST_STL is entered, the model will set CHPST_STL = 1.0. (Optional)
CHPST_RSP	Resuspension velocity for pesticide sorbed to sediment (m/day). If no value for CHPST_RSP is entered, the model will set CHPST_RSP = 0.002. (Optional)
CHPST_MIX	Mixing velocity (diffusion/dispersion) for pesticide in reach (m/day). If no value for CHPST_MIX is entered, the model will set CHPST_MIX = 0.001. (Optional)
SEDPST_CONC	Initial pesticide concentration in reach bed sediment (mg/m^3 sediment). (Optional)
SEDPST_REA	Pesticide reaction coefficient in reach bed sediment (day^{-1}). If no value for SEDPST_REA is entered, the model will set SEDPST_REA = 0.05. (Optional)
SEDPST_BRY	Pesticide burial velocity in reach bed sediment (m/day). If no value for SEDPST_BRY is entered, the model will set SEDPST_BRY = 0.002. (Optional)
SEDPST_ACT	Depth of active sediment layer for pesticide (m). If no value for SEDPST_ACT is entered, the model will set SEDPST_ACT = 0.03. (Optional)

The stream water quality file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the stream water quality input file is:

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
NUTRIENT TITLE	2	character	a80
DISOX	3	real	free

Variable name	**Line #**	**Format**	**F90 Format**
BOD	4	real	free
ALGAE	5	real	free
ORGANICN	6	real	free
AMMONIAN	7	real	free
NITRITEN	8	real	free
NITRATEN	9	real	free
ORGANICP	10	real	free
DISOLVP	11	real	free
RS1	12	real	free
RS2	13	real	free
RS3	14	real	free
RS4	15	real	free
RS5	16	real	free
RS6	17	real	free
RS7	18	real	free
RK1	19	real	free
RK2	20	real	free
RK3	21	real	free
RK4	22	real	free
RK5	23	real	free
RK6	24	real	free
BC1	25	real	free
BC2	26	real	free
BC3	27	real	free
BC4	28	real	free
PESTICIDE TITLE	29	character	a80
CHPST_CONC	30	real	free
CHPST_REA	31	real	free
CHPST_VOL	32	real	free
CHPST_KOC	33	real	free
CHPST_STL	34	real	free
CHPST_RSP	35	real	free
CHPST_MIX	36	real	free
SEDPST_CONC	37	real	free
SEDPST_REA	38	real	free

Variable name	Line #	Format	F90 Format
SEDPST_BRY	39	real	free
SEDPST_ACT	40	real	free

41.3 LAKE WATER QUALITY INPUT FILE (.LWQ)

The lake water quality input file contains information used by SWAT to model nutrient and pesticide water quality in reservoirs.

Following is a brief description of the variables in the lake water quality input file. They are listed in the order they appear within the file.

Variable name	**Definition**
TITLE	The first line is reserved for user comments. This line is not processed by the model.
NUTRIENT TITLE	The second line is reserved for the nutrient section title. This line is not processed by the model.
IRES1	Beginning month of mid-year nutrient settling period. Optional.
IRES2	Ending month of mid-year nutrient settling period. Optional.
PSETLR1	Phosphorus settling rate in reservoir for months IRES1 through IRES2 (m/year). Optional.
PSETLR2	Phosphorus settling rate in reservoir for months other than IRES1-IRES2 (m/year). Optional.
NSETLR1	Nitrogen settling rate in reservoir for months IRES1 through IRES2 (m/year). Optional.
NSETLR2	Nitrogen settling rate in reservoir for months other than IRES1-IRES2 (m/year). Optional.
CHLAR	Chlorophyll *a* production coefficient for reservoir. Chlorophyll *a* concentration in the reservoir is calculated from the total phosphorus concentration. The equation assumes the system is phosphorus limited. The chlorophyll *a* coefficient was added to the equation to allow the user to adjust results to account for other factors not taken into account by the basic equation such as nitrogen limitations. The default value for CHLA is 1.00, which uses the original equation. Optional.

Variable name	Definition
SECCIR	Water clarity coefficient for the reservoir. The clarity of the reservoir is expressed by the secci-disk depth (m) which is calculated as a function of chlorophyll *a*. Because suspended sediment also can affect water clarity, the water clarity coefficient has been added to the equation to allow users to adjust for the impact of factors other than chlorophyll *a* on water clarity. The default value for SECCI is 1.00, which uses the original equation. Optional.
RES_ORGP	Initial concentration of organic P in reservoir (mg P/L). Optional.
RES_SOLP	Initial concentration of soluble P in reservoir (mg P/L). Optional.
RES_ORGN	Initial concentration of organic N in reservoir (mg N/L). Optional.
RES_NO3	Initial concentration of NO_3-N in reservoir (mg N/L). Optional.
RES_NH3	Initial concentration of NH_3-N in reservoir (mg N/L). Optional.
RES_NO2	Initial concentration of NO_2-N in reservoir (mg N/L). Optional.
PESTICIDE TITLE	This line is reserved for the pesticide section title. This line is not processed by the model.
LKPST_CONC	Initial pesticide concentration in the reservoir water for the pesticide defined by IRTPEST (.bsn). While up to ten pesticides may be applied in a SWAT simulation, only one pesticide (IRTPEST) is routed through the channel network. (mg/m^3)
LKPST_REA	Reaction coefficient of the pesticide in reservoir water (day^{-1})
LKPST_VOL	Volatilization coefficient of the pesticide from the reservoir water (m/day)
LKPST_KOC	Partition coefficient (m^3/day)
LKPST_STL	Settling velocity of pesticide sorbed to sediment (m/day)
LKPST_RSP	Resuspension velocity of pesticide sorbed to sediment (m/day).

Variable name	Definition
LKPST_MIX	Mixing velocity (m/day)
LKSPST_CONC	Initial pesticide concentration in the reservoir bottom sediments. (mg/m^3)
LKSPST_REA	Reaction coefficient of pesticide in reservoir bottom sediment (day^{-1})
LKSPST_BRY	Burial velocity of pesticide in reservoir bottom sediment (m/day)
LKSPST_ACT	Depth of active sediment layer in reservoir (m)

The lake water quality file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the lake water quality input file is:

Variable name	Line #	Format	F90 Format
TITLE	1	character	a80
NUTRIENT TITLE	2	character	a80
IRES1	3	integer	free
IRES2	4	integer	free
PSETLR1	5	real	free
PSETLR2	6	real	free
NSETLR1	7	real	free
NSETLR2	8	real	free
CHLAR	9	real	free
SECCIR	10	real	free
RES_ORGP	11	real	free
RES_SOLP	12	real	free
RES_ORGN	13	real	free
RES_NO3	14	real	free
RES_NH3	15	real	free
RES_NO2	16	real	free

Variable name	**Line #**	**Format**	**F90 Format**
PESTICIDE TITLE	17	character	a80
LKPST_CONC	18	real	free
LKPST_REA	19	real	free
LKPST_VOL	20	real	free
LKPST_KOC	21	real	free
LKPST_STL	22	real	free
LKPST_RSP	23	real	free
LKPST_MIX	24	real	free
LKSPST_CONC	25	real	free
LKSPST_REA	26	real	free
LKSPST_BRY	27	real	free
LKSPST_ACT	28	real	free

CHAPTER 42

SWAT INPUT DATA: DATABASES

SWAT uses five databases to store information required for plant growth, urban land characteristics, tillage, fertilizer components and pesticide properties. These databases are supplied with the model. The following sections summarize the required information needed within the five databases.

42.1 LAND COVER/PLANT GROWTH DATABASE FILE (CROP.DAT)

Following is a brief description of the variables in the land cover/plant growth database file. They are listed in the order they appear within the file.

Variable name	Definition
ICNUM	Land cover/plant code. The different plants listed in crop.dat must have consecutive values for ICNUM. ICNUM is the numeric code used in the management file to identify the land cover to be modeled.
CPNM	A four character code to represent the land cover/plant name. This code is printed to the output files.
IDC	Land cover/plant classification: 1 warm season annual legume 2 cold season annual legume 3 perennial legume 4 warm season annual 5 cold season annual 6 perennial 7 trees
DESCRIPTION	Full land cover/plant name. This description is not used by the model and is present to assist the user in differentiating between plant species.
BIO_E	Radiation-use efficiency or biomass-energy ratio ((kg/ha)/(MJ/m^2)). This is the potential (unstressed) growth rate (including roots) per unit of intercepted photosynthetically active radiation. This parameter can greatly change the rate of growth, incidence of stress during the season and the resultant yield. This parameter should be one of the last to be adjusted. Adjustments should be based on research results. Care should be taken to make adjustments based only on data with no drought, nutrient or temperature stress.
HVSTI	Harvest index. This is the plant yield divided by the total aboveground biomass ((kg/ha)/(kg/ha)). This plant parameter should be based on experimental data where crop stresses have been minimized to allow the crop to attain its potential. SWAT will adjust the harvest index if water stress occurs near flowering.

Variable name	Definition
BLAI	Maximum potential leaf area index. The values for BLAI in the plant growth database are based on average plant densities in dryland (rainfed) agriculture. BLAI may need to be adjusted for drought-prone regions where planting densities are much smaller or irrigated conditions where densities are much greater.
FRGRW1	Fraction of the plant growing season or fraction of total potential heat units corresponding to the 1st point on the optimal leaf area development curve. The total potential heat units are the number of heat units required to bring the plant to maturity.
LAIMX1	Fraction of the maximum leaf area index corresponding to the 1st point on the optimal leaf area development curve.
FRGRW2	Fraction of the plant growing season or fraction of total potential heat units corresponding to the 2nd point on the optimal leaf area development curve. The total potential heat units are the number of heat units required to bring the plant to maturity.
LAIMX2	Fraction of the maximum leaf area index corresponding to the 2nd point on the optimal leaf area development curve.
DLAI	Fraction of growing season when leaf area declines (heat units/heat units).
CHTMX	Maximum canopy height (m).
RDMX	Maximum root depth (m).
T_OPT	Optimal temperature for plant growth (ºC). Both optimal and base temperatures are very stable for cultivars within a species.
T_BASE	Minimum (base) temperature for plant growth (ºC).
CNYLD	Normal fraction of nitrogen in yield (kg N/kg yield). This value is estimated on a dry weight basis.
CPYLD	Normal fraction of phosphorus in yield (kg P/kg yield). This value is estimated on a dry weight basis.
BN(1)	Nitrogen uptake parameter #1: normal fraction of nitrogen in plant biomass at emergence (kg N/kg biomass)
BN(2)	Nitrogen uptake parameter #2: normal fraction of nitrogen in plant biomass at 50% maturity (kg N/kg biomass)

Variable name	Definition
BN(3)	Nitrogen uptake parameter #3: normal fraction of nitrogen in plant biomass at maturity (kg N/kg biomass)
BP(1)	Phosphorus uptake parameter #1: normal fraction of phosphorus in plant biomass at emergence (kg P/kg biomass)
BP(2)	Phosphorus uptake parameter #2: normal fraction of phosphorus in plant biomass at 50% maturity (kg P/kg biomass)
BP(3)	Phosphorus uptake parameter #3: normal fraction of phosphorus in plant biomass at maturity (kg P/kg biomass)
WSYF	Lower limit of harvest index ((kg/ha)/(kg/ha)). The value between 0.0 and HVSTI which represents the lowest harvest index expected due to water stress.
USLE_C	Minimum value of USLE C factor for water erosion applicable to the land cover/plant.
GSI	Maximum stomatal conductance at high solar radiation and low vapor pressure deficit ($m \cdot s^{-1}$). Used in Penman-Monteith evapotranspiration calculations.
VPDFR	Vapor pressure deficit (kPa) corresponding to the second point on the stomatal conductance curve. (The first point on the stomatal conductance curve is comprised of a vapor pressure deficit of 1 kPa and the fraction of maximum stomatal conductance equal to 1.00.)
FRGMAX	Fraction of maximum stomatal conductance corresponding to the second point on the stomatal conductance curve. (The first point on the stomatal conductance curve is comprised of a vapor pressure deficit of 1 kPa and the fraction of maximum stomatal conductance equal to 1.00.)
WAVP	Rate of decline in radiation use efficiency per unit increase in vapor pressure deficit. The value of WAVP varies among species, but a value of 6 to 8 is suggested as an approximation for most plants.
CO2HI	Elevated CO_2 atmospheric concentration (μL CO_2/L air) corresponding the 2^{nd} point on the radiation use efficiency curve. (The 1^{st} point on the radiation use efficiency curve is comprised of the ambient CO_2 concentration, 330 μL CO_2/L air, and the biomass-energy ratio reported for BIO_E)

Variable name	Definition
BIOEHI	Biomass-energy ratio corresponding to the 2nd point on the radiation use efficiency curve. (The 1st point on the radiation use efficiency curve is comprised of the ambient CO_2 concentration, 330 μL CO_2/L air, and the biomass-energy ratio reported for BIO_E.)
RSDCO_PL	Plant residue decomposition coefficient. The fraction of residue that will decompose in a day assuming optimal moisture, temperature, C:N ratio, and C:P ratio. Optional. If no value is entered for RSDCO_PL, it is set equal to the value given for RSDCO in the watershed general attribute (.bsn) file.

42.1.1 FILE FORMAT (CROP.DAT)

Four lines are required to store the plant growth parameters for a land cover/plant in the database (crop.dat) file. The plant growth database file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line.

Variable name	Line #	Format	F90 Format
ICNUM	1	integer	free
CPNM	1	character	a4
IDC	1	integer	free
BIO_E	2	real	free
HVSTI	2	real	free
BLAI	2	real	free
FRGRW1	2	real	free
LAIMX1	2	real	free
FRGRW2	2	real	free
LAIMX2	2	real	free
DLAI	2	real	free
CHTMX	2	real	free
RDMX	2	real	free
T_OPT	3	real	free
T_BASE	3	real	free

Variable name	Line #	Format	F90 Format
CNYLD	3	real	free
CPYLD	3	real	free
BN(1)	3	real	free
BN(2)	3	real	free
BN(3)	3	real	free
BP(1)	3	real	free
BP(2)	3	real	free
BP(3)	3	real	free
WSYF	4	real	free
USLE_C	4	real	free
GSI	4	real	free
VPDFR	4	real	free
FRGMAX	4	real	free
WAVP	4	real	free
CO2HI	4	real	free
BIOEHI	4	real	free
RSDCO_PL	4	real	free

42.2 TILLAGE DATABASE FILE (TILL.DAT)

Following is a brief description of the variables in the tillage database file. They are listed in the order they appear within the file.

Variable name	Definition
ITNUM	Tillage number. The different tillage operations in till.dat must have consecutive values for ITNUM. ITNUM is the numeric code used in the management file to identify the tillage practice to be modeled.
TILLNM	An eight character code representing the tillage operation name.
EFFMIX	Mixing efficiency of tillage operation. The mixing efficiency specifies the fraction of materials (residue and nutrients) on the soil surface which are mixed uniformly throughout the soil depth mixed by the implement. The remaining fraction of residue and nutrients is left in the original location (soil surface or layer).
DEPTIL	Depth of mixing caused by the tillage operation (mm).

The format of the tillage database file is:

Variable name	Line #	Position	Format	F90 Format
ITNUM	ALL	space 1-4	4-digit integer	i4
TILLNM	ALL	space 9-16	character	a8
EFFMIX	ALL	space 25-32	decimal(xxxx.xxx)	f8.3
DEPTIL	ALL	space 41-48	decimal(xxxx.xxx)	f8.3

42.3 PESTICIDE/TOXIN DATABASE FILE (PEST.DAT)

Following is a brief description of the variables in the pesticide/toxin database file. They are listed in the order they appear within the file.

Variable name	Definition
IPNUM	Pesticide/toxin number. The different toxins in pest.dat must have consecutive values for IPNUM. IPNUM is the numeric code used in the management file to identify the pesticide/toxin to be applied.
PNAME	Name of pesticide/toxin. (up to 17 characters allowed)
SKOC	Soil adsorption coefficient normalized for soil organic carbon content (mg/kg)/(mg/L). K_{oc} is equal to the soil adsorption coefficient, K_p, divided by the fraction of organic carbon in the soil. K_p is calculated by dividing $C_{solid\ phase}$ by $C_{solution}$ where $C_{solid\ phase}$ is the concentration of the chemical sorbed to the solid phase (expressed as mg chemical/kg solid material) and $C_{solution}$ is the concentration of the chemical in the solution (expressed as mg chemical/L solution). K_{oc} and K_p have the same units.
WOF	Wash-off fraction. Fraction of pesticide on foliage available for wash off by rainfall (0.0-1.0). The pesticide is deposited on the soil surface.
HLIFE_F	Degradation half-life of the chemical on the foliage (days).
HLIFE_S	Degradation half-life of the chemical in the soil (days).
AP_EF	Application efficiency. The fraction of pesticide applied which is deposited on the foliage and soil surface (0.1-1.0). The remainder is lost.
WSOL	Solubility of the chemical in water (mg/L or ppm)

Variable name	Definition
HENRY	Henry's Law Constant (K_H) for the chemical (unitless). Henry's Law Constant characterizes the partitioning of the chemical between the air and water. Values for Henry's Law are reported in several different units and care must be taken when obtaining values to make sure they are in the correct units. For calculations in SWAT, K_H is defined as $C_{gas}/C_{solution}$ where C_{gas} is the concentration of the chemical in the gas phase (mg/L) and $C_{solution}$ is defined as the concentration of the chemical in solution. (*not currently operational*)

The format of the pesticide/toxin database file is:

Variable name	Line #	Position	Format	F90 Format
IPNUM	ALL	space 1-3	integer	i3
PNAME	ALL	space 4-20	character	a17
SKOC	ALL	space 21-30	decimal(xxxxxxxx.x)	f10.1
WOF	ALL	space 31-35	decimal(xx.xx)	f5.2
HLIFE_F	ALL	space 36-43	decimal(xxxxxx.x)	f8.1
HLIFE_S	ALL	space 44-51	decimal(xxxxxx.x)	f8.1
AP_EF	ALL	space 52-56	decimal(xx.xx)	f5.2
WSOL	ALL	space 57-67	decimal(xxxxxxx.xxx)	f11.3
HENRY	ALL	space 68-79	exponential(x.xxxxExxx)	e12.4

42.4 FERTILIZER DATABASE FILE (FERT.DAT)

Following is a brief description of the variables in the fertilizer database file. They are listed in the order they appear within the file.

Variable name	Definition
IFNUM	Number of fertilizer in database. This number should be equivalent to the line number and is the reference number used in the management file to identify the fertilizer type being applied.
FERTNM	Name of fertilizer/manure (up to 8 characters allowed).
FMINN	Fraction of mineral N (NO_3 and NH_4) in fertilizer (kg min-N/kg fertilizer). Value should be between 0.0 and 1.0.
FMINP	Fraction of mineral P in fertilizer (kg min-P/kg fertilizer). Value should be between 0.0 and 1.0.
FORGN	Fraction of organic N in fertilizer (kg org-N/kg fertilizer). Value should be between 0.0 and 1.0.
FORGP	Fraction of organic P in fertilizer (kg org-P/kg fertilizer). Value should be between 0.0 and 1.0.
FNH3N	Fraction of mineral N in fertilizer applied as ammonia (kg NH_3-N/kg min-N). Value should be between 0.0 and 1.0.
BACTPDB	Concentration of persistent bacteria in manure/fertilizer (# bacteria/kg manure). Optional.
BACTLPDB	Concentration of less-persistent bacteria in manure/fertilizer (# bacteria/kg manure). Optional.
BACTKDDB	Bacteria partition coefficient. Value should be between 0.0 and 1.0. When the bacteria partition coefficient is 0.0, all bacteria are sorbed to soil particles. When the bacteria partition coefficient is 1.0 all bacteria is in solution. Optional.

The format of the fertilizer database file is:

Variable name	Line #	Position	Format	F90 Format
IFNUM	ALL	space 1-4	integer	i4
FERTNM	ALL	space 6-13	character	a8
FMINN	ALL	space 14-21	decimal(xxxx.xxx)	f8.3
FMINP	ALL	space 22-29	decimal(xxxx.xxx)	f8.3
FORGN	ALL	space 30-37	decimal(xxxx.xxx)	f8.3
FORGP	ALL	space 38-45	decimal(xxxx.xxx)	f8.3
FNH3N	ALL	space 46-53	decimal(xxxx.xxx)	f8.3
BACTPDB	ALL	space 54-61	decimal(xxxx.xxx)	f8.3
BACTLPDB	ALL	space 62-69	decimal(xxxx.xxx)	f8.3
BACTKDDB	ALL	space 70-77	decimal(xxxx.xxx)	f8.3

42.5 URBAN DATABASE FILE (URBAN.DAT)

Following is a brief description of the variables in the urban database file. They are listed in the order they appear within the file.

Variable name	Definition
IUNUM	Number of urban land type. This value should be equivalent to the line number.
URBNAME	4-character code for urban land type.
URBFLNM	Full description for urban land type—may take up to 54 characters. (not used by SWAT)
FIMP	Fraction total impervious area in urban land type. This includes directly and indirectly connected impervious areas.
FCIMP	Fraction directly connected impervious area in urban land type.
CURBDEN	Curb length density in urban land type (km/ha).
URBCOEF	Wash-off coefficient for removal of constituents from impervious area (mm^{-1})
DIRTMX	Maximum amount of solids allowed to build up on impervious areas (kg/curb km).
THALF	Number of days for amount of solids on impervious areas to build up from 0 kg/curb km to half the maximum allowed, i.e. 1/2 DIRTMX (days).
TNCONC	Concentration of total nitrogen in suspended solid load from impervious areas (mg N/kg sed).
TPCONC	Concentration of total phosphorus in suspended solid load from impervious areas (mg P/kg sed).
TNO3CONC	Concentration of nitrate in suspended solid load from impervious areas (mg NO_3-N/kg sed).

Every urban land type uses two lines in the urban.dat file to store input values. The format of every set of two lines is described below.

Variable name	Line #	Position	Format	F90 Format
IUNUM	1	space 1-3	integer	i3
URBNAME	1	space 5-8	character	a4
URBFLNM	1	space 10-64	character	a54
FIMP	1	space 65-72	decimal(xxxx.xxx)	f8.3
FCIMP	1	space 73-80	decimal(xxxx.xxx)	f8.3
CURBDEN	2	space 5-12	decimal(xxxx.xxx)	f8.3
URBCOEF	2	space 13-20	decimal(xxxx.xxx)	f8.3
DIRTMX	2	space 21-28	decimal(xxxx.xxx)	f8.3
THALF	2	space 29-36	decimal(xxxx.xxx)	f8.3
TNCONC	2	space 37-44	decimal(xxxx.xxx)	f8.3
TPCONC	2	space 45-52	decimal(xxxx.xxx)	f8.3
TNO3CONC	2	space 53-60	decimal(xxxx.xxx)	f8.3

CHAPTER 43

SWAT INPUT DATA: MEASURED

Four different file formats may be used to store stream loading data that is incorporated directly into the watershed routing. This stream loading data may come from a point source, such as a town's sewage treatment discharge, or it may be output from simulation of an upstream area. The four different file formats allow the user to summarize the data in one of four ways: daily, monthly, yearly, or average annual.

43.1 DAILY RECORDS (RECDAY .DAT FILE)

The recday command in the watershed configuration (.fig) file requires a file containing SWAT input data summarized on a daily time step.

An unlimited* number of files with daily flow data are allowed in the simulation. The file numbers assigned to the recday files in the watershed configuration file (.fig) must be ≥ 1 and numbered sequentially.

Following is a brief description of the variables in the recday input file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first six lines of the file are reserved for user comments. The comments may take up to 80 spaces per line.
DAY	Julian date for record (optional). If the julian date and year are provided for the records, SWAT will search for the beginning day of simulation in the record. If the julian date and year are left blank, SWAT assumes that the first line of record corresponds to the first day of simulation. (SWAT uses the date and year to locate the record corresponding to the first day of simulation. From that point on, the day and year are ignored.)
YEAR	Four-digit year for record (optional). See description of DAY for more information.
FLODAY	Contribution to streamflow for the day (m^3)
SEDDAY	Sediment loading to reach for the day (metric tons)
ORGNDAY	Organic N loading to reach for the day (kg N)
ORGPDAY	Organic P loading to reach for the day (kg P)
NO3DAY	NO_3 loading to reach for the day (kg N)
MINPDAY	Mineral P loading to reach for the day (kg P)
NH3DAY	NH_3 loading to reach for the day (kg N)
NO2DAY	NO_2 loading to reach for the day (kg N)
CMTL1DAY	Loading of conservative metal #1 to reach for the day (kg)

* Please keep in mind that FORTRAN limits the total number of files that can be open at one time to something in the neighborhood of 250. The input files containing daily data (.pcp, .tmp, and recday) remain open throughout the simulation.

Variable name	Definition
CMTL2DAY	Loading of conservative metal #2 to reach for the day (kg)
CMTL3DAY	Loading of conservative metal #3 to reach for the day (kg)
BACTPDAY	Loading of persistent bacteria to reach for the day (# bact)
BACTLPDAY	Loading of less persistent bacteria to reach for the day (# bact)

One line of data is required for every day of the simulation period. The recday data file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the recday data file is:

Variable name	Line #	Format	F90 Format
TITLE	1 - 6	character	a80
DAY	7-END	integer	free
YEAR	7-END	integer	free
FLODAY	7-END	real or exponential	free
SEDDAY	7-END	real or exponential	free
ORGNDAY	7-END	real or exponential	free
ORGPDAY	7-END	real or exponential	free
NO3DAY	7-END	real or exponential	free
MINPDAY	7-END	real or exponential	free
NH3DAY	7-END	real or exponential	free
NO2DAY	7-END	real or exponential	free
CMTL1DAY	7-END	real or exponential	free
CMTL2DAY	7-END	real or exponential	free
CMTL3DAY	7-END	real or exponential	free
BACTPDAY	7-END	real or exponential	free
BACTLPDAY	7-END	real or exponential	free

43.2 MONTHLY RECORDS (RECMON .DAT FILE)

The recmon command in the watershed configuration (.fig) file requires a file containing input data summarized on a monthly time step.

SWAT will accept an unlimited number of data files with monthly flow data. The file numbers assigned to the files in the watershed configuration file (.fig) must be numbered sequentially and begin at 1.

Following is a brief description of the variables in the recmon data file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first 6 lines of the data file is reserved for user comments. The comments may take up to 80 spaces.
MONTH	Month of measured data. This variable is provided for the user—it is ignored by SWAT. The model assumes the first line of measured data in the file contains data for January of the first year of simulation. The monthly data file must contain a line of data for every month of simulation in consecutive order.
YEAR	4-digit year of measured data. This variable is provided for the user—it is ignored by SWAT. The model assumes the first line of measured data in the file contains data for January of the first year of simulation. The monthly data file must contain a line of data for every month of simulation in consecutive order.
FLOMON	Average daily water loading for month (m^3/day).
SEDMON	Average daily sediment loading for month (metric tons/day).
ORGNMON	Average daily organic nitrogen loading for month (kg N/day).
ORGPMON	Average daily organic phosphorus loading for month (kg P/day).
NO3MON	Average daily nitrate loading for month (kg N/day).
MINPMON	Average daily mineral (soluble) P loading for month (kg P/day).

Variable name	Definition
NH3MON	Average daily ammonia loading for month (kg N/day).
NO2MON	Average daily nitrite loading for month (kg N/day).
CMTL1MON	Average daily loading of conservative metal #1 for month (kg/day).
CMTL2MON	Average daily loading of conservative metal #2 for month (kg/day).
CMTL3MON	Average daily loading of conservative metal #3 for month (kg /day).
BACTPMON	Average daily loading of persistent bacteria for month (# bact/day).
BACTLPMON	Average daily loading of less persistent bacteria for month (# bact/day).

The file must contain one line of data for every month of simulation (Even if the simulation begins in a month other than January, the file must contain lines for every month of the first year.) The recmon data file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line. The format of the recmon data file is:

Variable name	Line #	Format	F90 Format
TITLE	1-6	character	a80
MONTH	7 - END	integer	free
YEAR	7 - END	integer	free
FLOMON	7 - END	real or exponential	free
SEDMON	7 - END	real or exponential	free
ORGNMON	7 - END	real or exponential	free
ORGPMON	7 - END	real or exponential	free
NO3MON	7 - END	real or exponential	free
MINPMON	7 - END	real or exponential	free
NH3MON	7 - END	real or exponential	free
NO2MON	7 - END	real or exponential	free
CMTL1MON	7 - END	real or exponential	free
CMTL2MON	7 - END	real or exponential	free
CMTL3MON	7 - END	real or exponential	free

Variable name	Line #	Format	F90 Format
BACTPMON	7 - END	real or exponential	free
BACTLPMON	7 - END	real or exponential	free

43.3 YEARLY RECORDS (RECYEAR .DAT FILE)

The recyear command in the watershed configuration (.fig) file requires a file containing SWAT input data summarized on an annual time step.

SWAT will accept an unlimited number of data files with yearly flow data. The file numbers assigned to the recyear files in the watershed configuration file (.fig) must be numbered sequentially and begin at 1.

Following is a brief description of the variables in the recyear data file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first six lines of the data file are reserved for user comments. The comments may take up to 80 spaces per line.
YEAR	4-digit year of measured data. This variable is provided for the user—it is ignored by SWAT. The model assumes the first line of measured data in the file contains data for the first year of simulation. The yearly data file must contain a line of data for every year of simulation in consecutive order.
FLOYR	Average daily water loading for year (m^3/day).
SEDYR	Average daily sediment loading for year (metric tons/day).
ORGNYR	Average daily organic nitrogen loading for year (kg N/day).
ORGPYR	Average daily organic phosphorus loading for year (kg P/day).
NO3YR	Average daily nitrate loading for year (kg N/day).

Variable name	Definition
MINPYR	Average daily mineral (soluble) P loading for year (kg P/day).
NH3YR	Average daily ammonia loading for year (kg N/day).
NO2YR	Average daily nitrite loading for year (kg N/day).
CMTL1YR	Average daily loading of conservative metal #1 for year (kg/day).
CMTL2YR	Average daily loading of conservative metal #2 for year (kg/day).
CMTL3YR	Average daily loading of conservative metal #3 for year (kg/day).
BACTPYR	Average daily loading of persistent bacteria for year (# bact/day).
BACTLPYR	Average daily loading of less persistent bacteria for year (# bact/day).

The recyear data file is a free format file. The variables may be placed in any position the user wishes on the line. Values for variables classified as integers *should not* include a decimal while values for variables classified as reals *must* contain a decimal. A blank space denotes the end of an input value and the beginning of the next value if there is another on the line.The format of the recyear data file is:

Variable name	Line #	Format	F90 Format
TITLE	1 - 6	character	a80
YEAR	7 - END	integer	free
FLOYR	7 - END	real or exponential	free
SEDYR	7 - END	real or exponential	free
ORGNYR	7 - END	real or exponential	free
ORGPYR	7 - END	real or exponential	free
NO3YR	7 - END	real or exponential	free
MINPYR	7 - END	real or exponential	free
NH3YR	7 - END	real or exponential	free
NO2YR	7 - END	real or exponential	free
CMTL1YR	7 - END	real or exponential	free
CMTL2YR	7 - END	real or exponential	free
CMTL3YR	7 - END	real or exponential	free

Variable name	Line #	Format	F90 Format
BACTPYR	7 - END	real or exponential	free
BACTLPYR	7 - END	real or exponential	free

43.4 AVERAGE ANNUAL RECORDS (RECCNST .DAT FILE)

The reccnst command in the watershed configuration (.fig) file requires a file containing average annual SWAT input data.

SWAT will accept an unlimited number of data files with average annual flow data. The file numbers assigned to the reccnst files in the watershed configuration file (.fig) must be numbered sequentially and begin at 1.

Following is a brief description of the variables in the reccnst data file. They are listed in the order they appear within the file.

Variable name	Definition
TITLE	The first six lines of the data file are reserved for user comments. The comments may take up to 80 spaces on each line.
FLOCNST	Average daily water loading (m^3/day)
SEDCNST	Average daily sediment loading (metric tons/day)
ORGNCNST	Average daily organic N loading (kg N/day)
ORGPCNST	Average daily organic P loading (kg P/day)
NO3CNST	Average daily NO_3 loading (kg N/day)
MINPCNST	Average daily mineral P loading (kg P/day)
NH3CNST	Average daily NH_3 loading (kg N/day)
NO2CNST	Average daily NO_2 loading (kg N/day)
CMTL1CNST	Average daily loading of conservative metal #1 (kg/day)
CMTL2CNST	Average daily loading of conservative metal #2 (kg/day)
CMTL3CNST	Average daily loading of conservative metal #3 (kg/day)
BACTPCNST	Average daily loading of persistent bacteria (# bact/day)
BACTLPCNST	Average daily loading of less persistent bacteria (# bact/day)

The format of the reccnst data file is:

Variable name	Line #	Format	F90 Format
TITLE	1-6	character	a80
FLOCNST	7	real or exponential	free
SEDCNST	7	real or exponential	free
ORGNCNST	7	real or exponential	free
ORGPCNST	7	real or exponential	free
NO3CNST	7	real or exponential	free
MINPCNST	7	real or exponential	free
NH3CNST	7	real or exponential	free
NO2CNST	7	real or exponential	free
CMTL1CNST	7	real or exponential	free
CMTL2CNST	7	real or exponential	free
CMTL3CNST	7	real or exponential	free
BACTPCNST	7	real or exponential	free
BACTLPCNST	7	real or exponential	free

CHAPTER 44

SWAT OUTPUT DATA: PRIMARY OUTPUT FILES

A number of output files are generated in every SWAT simulation. These files are: the summary output file (output.std), the HRU output file (.sbs), the subbasin output file (.bsb), and the main channel or reach output file (.rch).

The detail of the data printed out in each file is controlled by the print codes in the input control code (.cod) file. Average daily values are always printed in the HRU, subbasin and reach files, but the time period they are summarized over will vary. Depending on the print code selected, the output files may include all daily values, daily amounts averaged over the month, daily amounts averaged over the year, or daily amounts averaged over the entire simulation period.

44.1 INPUT SUMMARY FILE (INPUT.STD)

The input summary file prints summary tables of important input values. This file provides the user with a mechanism to spot-check input values. All model inputs are not printed, but the file does contain some of the most important.

44.2 OUTPUT SUMMARY FILE (OUTPUT.STD)

The output summary file provides watershed average loadings from the HRUs to the streams. Tables are also included that present average annual HRU and subbasin values for a few parameters.

44.3 HRU OUTPUT FILE (.SBS)

The HRU output file contains summary information for each of the hydrologic response units in the watershed. The file is written in spreadsheet format.

Following is a brief description of the output variables in the HRU output file.

Variable name	Definition
LULC	Four letter character code for the cover/plant on the HRU. (code from crop.dat file)
HRU	Hydrologic response unit number
GIS	GIS code reprinted from watershed configuration file (.fig). See explanation of subbasin command.
SUB	Topographically-defined subbasin to which the HRU belongs.
MGT	Management number. This is pulled from the management (.mgt) file. Used by the SWAT/GRASS interface to allow development of output maps by landuse/management type.
MON	Daily time step: the julian date Monthly time step: the month (1-12) Annual time step: four-digit year Average annual summary lines: total number of years averaged together
AREA	Drainage area of the HRU (km^2).
PRECIP	Total amount of precipitation falling on the HRU during time step (mm H_2O).
SNOFALL	Amount of precipitation falling as snow, sleet or freezing rain during time step (water-equivalent mm H_2O).
SNOMELT	Amount of snow or ice melting during time step (water-equivalent mm H_2O).
IRR	Irrigation (mm H_2O). Amount of irrigation water applied to HRU during the time step.
PET	Potential evapotranspiration (mm H_2O). Potential evapotranspiration from the HRU during the time step.
ET	Actual evapotranspiration (soil evaporation and plant transpiration) from the HRU during the time step (mm H_2O).

Variable name	Definition
SW	Soil water content (mm H_2O). Amount of water in the soil profile at the end of the time period.
PERC	Water that percolates past the root zone during the time step (mm H_2O). There is usually a lag between the time the water leaves the bottom of the root zone and reaches the shallow aquifer. Over a long period of time, this variable should equal groundwater recharge (PERC = GW_RCHG as time $\rightarrow \infty$).
GW_RCHG	Recharge entering aquifers during time step (total amount of water entering shallow and deep aquifers during time step) (mm H_2O).
DA_RCHG	Deep aquifer recharge (mm H_2O). The amount of water from the root zone that recharges the deep aquifer during the time step. (shallow aquifer recharge = GW_RCHG - DA_RCHG)
REVAP	Water in the shallow aquifer returning to the root zone in response to a moisture deficit during the time step (mm H_2O). The variable also includes water uptake directly from the shallow aquifer by deep tree and shrub roots.
SA_IRR	Irrigation from shallow aquifer (mm H_2O). Amount of water removed from the shallow aquifer for irrigation during the time step.
DA_IRR	Irrigation from deep aquifer (mm H_2O). Amount of water removed from the deep aquifer for irrigation during the time step.
SA_ST	Shallow aquifer storage (mm H_2O). Amount of water in the shallow aquifer at the end of the time period.
DA_ST	Deep aquifer storage (mm H_2O). Amount of water in the deep aquifer at the end of the time period.
SURQ	Surface runoff contribution to streamflow in the main channel during time step (mm H_2O).
TLOSS	Transmission losses (mm H_2O). Water lost from tributary channels in the HRU via transmission through the bed. This water becomes recharge for the shallow aquifer during the time step. Net surface runoff contribution to the main channel streamflow is calculated by subtracting TLOSS from SURQ.
LATQ	Lateral flow contribution to streamflow (mm H_2O). Water flowing laterally within the soil profile that enters the main channel during time step.

Variable name	Definition
GW_Q	Groundwater contribution to streamflow (mm H_2O). Water from the shallow aquifer that enters the main channel during the time step. Groundwater flow is also referred to as baseflow.
WYLD	Water yield (mm H_2O). Total amount of water leaving the HRU and entering main channel during the time step. (WYLD = SURQ + LATQ + GWQ – TLOSS – pond abstractions)
SYLD	Sediment yield (metric tons/ha). Sediment from the HRU that is transported into the main channel during the time step.
USLE	Soil loss during the time step calculated with the USLE equation (metric tons/ha). This value is reported for comparison purposes only.
N_APP	Nitrogen fertilizer applied (kg N/ha). Total amount of nitrogen (mineral and organic) applied in fertilizer during the time step.
P_APP	Phosphorus fertilizer applied (kg P/ha). Total amount of phosphorus (mineral and organic) applied in fertilizer during the time step.
NAUTO	Nitrogen fertilizer auto-applied (kg N/ha). Total amount of nitrogen (mineral and organic) auto-applied during the time step.
PAUTO	Phosphorus fertilizer auto-applied (kg P/ha). Total amount of phosphorus (mineral and organic) auto-applied during the time step.
NGRZ	Nitrogen applied during grazing operation (kg N/ha). Total amount of nitrogen (mineral and organic) added to soil by grazing operation during the time step.
PGRZ	Phosphorus applied during grazing operation (kg P/ha). Total amount of phosphorus (mineral and organic) added to soil by grazing operation during the time step.
NRAIN	Nitrate added to soil profile by rain (kg N/ha).
NFIX	Nitrogen fixation (kg N/ha). Amount of nitrogen fixed by legumes during the time step.

Variable name	Definition
F-MN	Fresh organic to mineral N (kg N/ha). Mineralization of nitrogen from the fresh residue pool to the nitrate (80%) pool and active organic nitrogen (20%) pool during the time step. A positive value denotes a net gain in the nitrate and active organic pools from the fresh organic pool while a negative value denotes a net gain in the fresh organic pool from the nitrate and active organic pools.
A-MN	Active organic to mineral N (kg N/ha). Movement of nitrogen from the active organic pool to the nitrate pool during the time step.
A-SN	Active organic to stable organic N (kg N/ha). Movement of nitrogen from the active organic pool to the stable organic pool during the time step.
F-MP	Fresh organic to mineral P (kg P/ha). Mineralization of phosphorus from the fresh residue pool to the "active" mineral (80%) pool (P sorbed to soil surface) and the active organic (20%) pool. A positive value denotes a net gain in the active mineral and active organic pools from the fresh organic pool while a negative value denotes a net gain in the fresh organic pool from the active mineral and active organic pools.
AO-LP	Organic to labile mineral P (kg P/ha). Movement of phosphorus between the organic pool and the labile mineral pool during the time step. A positive value denotes a net gain in the labile pool from the organic pool while a negative value denotes a net gain in the organic pool from the labile pool.
L-AP	Labile to active mineral P (kg P/ha). Movement or transformation of phosphorus between the "labile" mineral pool (P in solution) and the "active" mineral pool (P sorbed to the surface of soil particles) during the time step. A positive value denotes a net gain in the active pool from the labile pool while a negative value denotes a net gain in the labile pool from the active pool.
A-SP	Active to stable P (kg P/ha). Movement or transformation of phosphorus between the "active" mineral pool (P sorbed to the surface of soil particles) and the "stable" mineral pool (P fixed in soil) during the time step. A positive value denotes a net gain in the stable pool from the active pool while a negative value denotes a net gain in the active pool from the stable pool.

Variable name	Definition
DNIT	Denitrification (kg N/ha). Transformation of nitrate to gaseous compounds during the time step.
NUP	Plant uptake of nitrogen (kg N/ha). Nitrogen removed from soil by plants during the time step.
PUP	Plant uptake of phosphorus (kg P/ha). Phosphorus removed from soil by plants during the time step.
ORGN	Organic N yield (kg N/ha). Organic nitrogen transported out of the HRU and into the reach during the time step.
ORGP	Organic P yield (kg P/ha). Organic phosphorus transported with sediment into the reach during the time step.
SEDP	Sediment P yield (kg P/ha). Mineral phosphorus sorbed to sediment transported into the reach during the time step.
NSURQ	NO_3 in surface runoff (kg N/ha). Nitrate transported with surface runoff into the reach during the time step.
NLATQ	NO_3 in lateral flow (kg N/ha). Nitrate transported by lateral flow into the reach during the time step.
NO3L	NO_3 leached from the soil profile (kg N/ha). Nitrate that leaches past the bottom of the soil profile during the time step. *The nitrate is not tracked through the shallow aquifer*.
NO3GW	NO_3 transported into main channel in the groundwater loading from the HRU (kg N/ha).
SOLP	Soluble P yield (kg P/ha). Soluble mineral forms of phosphorus transported by surface runoff into the reach during the time step.
P_GW	Soluble phosphorus transported by groundwater flow into main channel during the time step (kg P/ha).
W_STRS	Water stress days during the time step (days).
TMP_STRS	Temperature stress days during the time step (days).
N_STRS	Nitrogen stress days during the time step (days).
P_STRS	Phosphorus stress days during the time step (days).
BIOM	Biomass (metric tons/ha). Total biomass, i.e. aboveground and roots at the end of the time period reported as dry weight.
LAI	Leaf area index at the end of the time period.

Variable name	Definition
YLD	Harvested yield (metric tons/ha). The model partitions yield from the total biomass on a daily basis (and reports it). However, the actual yield is not known until it is harvested. The harvested yield is reported as dry weight.
BACTP	Number of persistent bacteria in surface runoff entering reach (count).
BACTLP	Number of less persistent bacteria in surface runoff entering reach (count).

The file format for the HRU output file (.sbs) is:

Variable name	Line #	Position	Format	F90 Format
LULC	All	space 1-4	character	a4
HRU	All	space 5-8	4-digit integer	i4
GIS	All	space 10-17	8-digit integer	i8
SUB	All	space 19-22	4-digit integer	i4
MGT	All	space 24-27	4-digit integer	i4
MON	All	space 29-32	4-digit integer	i4
AREA	All	space 33-42	decimal(xxxxxx.xxx)	f10.3
PRECIP	All	space 43-52	decimal(xxxxxx.xxx)	f10.3
SNOFALL	All	space 53-62	decimal(xxxxxx.xxx)	f10.3
SNOMELT	All	space 63-72	decimal(xxxxxx.xxx)	f10.3
IRR	All	space 73-82	decimal(xxxxxx.xxx)	f10.3
PET	All	space 83-92	decimal(xxxxxx.xxx)	f10.3
ET	All	space 93-102	decimal(xxxxxx.xxx)	f10.3
SW	All	space 103-112	decimal(xxxxxx.xxx)	f10.3
PERC	All	space 113-122	decimal(xxxxxx.xxx)	f10.3
GW_RCHG	All	space 123-132	decimal(xxxxxx.xxx)	f10.3
DA_RCHG	All	space 133-142	decimal(xxxxxx.xxx)	f10.3
REVAP	All	space 143-152	decimal(xxxxxx.xxx)	f10.3
SA_IRR	All	space 153-162	decimal(xxxxxx.xxx)	f10.3
DA_IRR	All	space 163-172	decimal(xxxxxx.xxx)	f10.3
SA_ST	All	space 173-182	decimal(xxxxxx.xxx)	f10.3
DA_ST	All	space 183-192	decimal(xxxxxx.xxx)	f10.3
SURQ	All	space 193-202	decimal(xxxxxx.xxx)	f10.3

Variable name	Line #	Position	Format	F90 Format
TLOSS	All	space 203-212	decimal(xxxxxx.xxx)	f10.3
LATQ	All	space 213-222	decimal(xxxxxx.xxx)	f10.3
GW_Q	All	space 223-232	decimal(xxxxxx.xxx)	f10.3
WYLD	All	space 233-242	decimal(xxxxxx.xxx)	f10.3
SYLD	All	space 243-252	decimal(xxxxxx.xxx)	f10.3
USLE	All	space 253-262	decimal(xxxxxx.xxx)	f10.3
N_APP	All	space 263-272	decimal(xxxxxx.xxx)	f10.3
P_APP	All	space 273-282	decimal(xxxxxx.xxx)	f10.3
NAUTO	All	space 283-292	decimal(xxxxxx.xxx)	f10.3
PAUTO	All	space 293-302	decimal(xxxxxx.xxx)	f10.3
NGRZ	All	space 303-312	decimal(xxxxxx.xxx)	f10.3
PGRZ	All	space 313-322	decimal(xxxxxx.xxx)	f10.3
NRAIN	All	space 323-332	decimal(xxxxxx.xxx)	f10.3
NFIX	All	space 333-342	decimal(xxxxxx.xxx)	f10.3
F-MN	All	space 343-352	decimal(xxxxxx.xxx)	f10.3
A-MN	All	space 353-362	decimal(xxxxxx.xxx)	f10.3
A-SN	All	space 363-372	decimal(xxxxxx.xxx)	f10.3
F-MP	All	space 373-382	decimal(xxxxxx.xxx)	f10.3
AO-LP	All	space 383-392	decimal(xxxxxx.xxx)	f10.3
L-AP	All	space 393-402	decimal(xxxxxx.xxx)	f10.3
A-SP	All	space 403-412	decimal(xxxxxx.xxx)	f10.3
DNIT	All	space 413-422	decimal(xxxxxx.xxx)	f10.3
NUP	All	space 423-432	decimal(xxxxxx.xxx)	f10.3
PUP	All	space 433-442	decimal(xxxxxx.xxx)	f10.3
ORGN	All	space 443-452	decimal(xxxxxx.xxx)	f10.3
ORGP	All	space 453-462	decimal(xxxxxx.xxx)	f10.3
SEDP	All	space 463-472	decimal(xxxxxx.xxx)	f10.3
NSURQ	All	space 473-482	decimal(xxxxxx.xxx)	f10.3
NLATQ	All	space 483-492	decimal(xxxxxx.xxx)	f10.3
NO3L	All	space 493-502	decimal(xxxxxx.xxx)	f10.3
NO3GW	All	space 503-512	decimal(xxxxxx.xxx)	f10.3
SOLP	All	space 513-522	decimal(xxxxxx.xxx)	f10.3
P_GW	All	space 523-532	decimal(xxxxxx.xxx)	f10.3
W_STRS	All	space 533-542	decimal(xxxxxx.xxx)	f10.3
TMP_STRS	All	space 543-552	decimal(xxxxxx.xxx)	f10.3

Variable name	**Line #**	**Position**	**Format**	**F90 Format**
N_STRS	All	space 553-562	decimal(xxxxxx.xxx)	f10.3
P_STRS	All	space 563-572	decimal(xxxxxx.xxx)	f10.3
BIOM	All	space 573-582	decimal(xxxxxx.xxx)	f10.3
LAI	All	space 583-592	decimal(xxxxxx.xxx)	f10.3
YLD	All	space 593-602	decimal(xxxxxx.xxx)	f10.3
BACTP	All	space 603-612	decimal(xxxxxx.xxx)	f10.3
BACTLP	All	space 613-622	decimal(xxxxxx.xxx)	f10.3

44.4 SUBBASIN OUTPUT FILE (.BSB)

The subbasin output file contains summary information for each of the subbasins in the watershed. The reported values for the different variables are the total amount or weighted average of all HRUs within the subbasin. The subbasin output file is written in spreadsheet format.

Following is a brief description of the output variables in the subbasin output file.

Variable name	Definition
SUB	Subbasin number.
GIS	GIS code reprinted from watershed configuration file (.fig). See explanation of subbasin command.
MON	Daily time step: julian date Monthly time step: the month (1-12) Annual time step: four-digit year Average annual summary lines: total number of years averaged together
AREA	Area of the subbasin (km^2).
PRECIP	Total amount of precipitation falling on the subbasin during time step (mm H_2O).
SNOMELT	Amount of snow or ice melting during time step (water-equivalent mm H_2O).
PET	Potential evapotranspiration from the subbasin during the time step (mm H_2O).
ET	Actual evapotranspiration from the subbasin during the time step (mm).
SW	Soil water content (mm). Amount of water in the soil profile at the end of the time period.

Variable name	Definition
PERC	Water that percolates past the root zone during the time step (mm). There is potentially a lag between the time the water leaves the bottom of the root zone and reaches the shallow aquifer. Over a long period of time, this variable should equal groundwater percolation.
SURQ	Surface runoff contribution to streamflow during time step (mm H_2O).
GW_Q	Groundwater contribution to streamflow (mm). Water from the shallow aquifer that returns to the reach during the time step.
WYLD	Water yield (mm H_2O). The net amount of water that leaves the subbasin and contributes to streamflow in the reach during the time step. (WYLD = SURQ + LATQ + GWQ – TLOSS – pond abstractions)
SYLD	Sediment yield (metric tons/ha). Sediment from the subbasin that is transported into the reach during the time step.
ORGN	Organic N yield (kg N/ha). Organic nitrogen transported out of the subbasin and into the reach during the time step.
ORGP	Organic P yield (kg P/ha). Organic phosphorus transported with sediment into the reach during the time step.
NSURQ	NO_3 in surface runoff (kg N/ha). Nitrate transported by the surface runoff into the reach during the time step.
SOLP	Soluble P yield (kg P/ha). Phosphorus that is transported by surface runoff into the reach during the time step.
SEDP	Mineral P yield (kg P/ha). Mineral phosphorus attached to sediment that is transported by surface runoff into the reach during the time step.

The format of the subbasin output file (.bsb) is:

Variable name	Line #	Position	Format	F90 Format
SUB	All	space 7-10	4-digit integer	i4
GIS	All	space 12-19	8-digit integer	i8
MON	All	space 21-24	4-digit integer	i4
AREA	All	space 25-34	decimal(xxxxxx.xxx)	f10.3
PRECIP	All	space 35-44	decimal(xxxxxx.xxx)	f10.3
SNOMELT	All	space 45-54	decimal(xxxxxx.xxx)	f10.3
PET	All	space 55-64	decimal(xxxxxx.xxx)	f10.3
ET	All	space 65-74	decimal(xxxxxx.xxx)	f10.3
SW	All	space 75-84	decimal(xxxxxx.xxx)	f10.3
PERC	All	space 85-94	decimal(xxxxxx.xxx)	f10.3
SURQ	All	space 95-104	decimal(xxxxxx.xxx)	f10.3
GW_Q	All	space 105-114	decimal(xxxxxx.xxx)	f10.3
WYLD	All	space 115-124	decimal(xxxxxx.xxx)	f10.3
SYLD	All	space 125-134	decimal(xxxxxx.xxx)	f10.3
ORGN	All	space 135-144	decimal(xxxxxx.xxx)	f10.3
ORGP	All	space 145-154	decimal(xxxxxx.xxx)	f10.3
NSURQ	All	space 155-164	decimal(xxxxxx.xxx)	f10.3
SOLP	All	space 165-174	decimal(xxxxxx.xxx)	f10.3
SEDP	All	space 175-184	decimal(xxxxxx.xxx)	f10.3

44.5 MAIN CHANNEL OUTPUT FILE (.RCH)

The main channel output file contains summary information for each routing reach in the watershed. The file is written in spreadsheet format.

Following is a brief description of the output variables in the .rch file.

Variable name	Definition
RCH	Reach number. The reach number is also the hydrograph number of the subbasin as defined in the .fig file.
GIS	GIS number reprinted from watershed configuration (.fig) file. See explanation of subbasin command.
MON	Daily time step: the julian date Monthly time step: the month (1-12) Annual time step: 4-digit year Average annual summary lines: number of years averaged together
AREA	Area drained by reach (km^2).
FLOW_IN	Average daily streamflow into reach during time step (m^3/s).
FLOW_OUT	Average daily streamflow out of reach during time step (m^3/s).
EVAP	Average daily rate of water loss from reach by evaporation during time step (m^3/s).
TLOSS	Average daily rate of water loss from reach by transmission through the streambed during time step (m^3/s).
SED_IN	Sediment transported with water into reach during time step (metric tons).
SED_OUT	Sediment transported with water out of reach during time step (metric tons).
SEDCONC	Concentration of sediment in reach during time step (mg/L).
ORGN_IN	Organic nitrogen transported with water into reach during time step (kg N).
ORGN_OUT	Organic nitrogen transported with water out of reach during time step (kg N).
ORGP_IN	Organic phosphorus transported with water into reach during time step (kg P).
ORGP_OUT	Organic phosphorus transported with water out of reach during time step (kg P).

Variable name	Definition
NO3_IN	Nitrate transported with water into reach during time step (kg N).
NO3_OUT	Nitrate transported with water out of reach during time step (kg N).
NH4_IN	Ammonium transported with water into reach during time step (kg N).
NH4_OUT	Ammonium transported with water out of reach during time step (kg N).
NO2_IN	Nitrite transported with water into reach during time step (kg N).
NO2_OUT	Nitrite transported with water out of reach during time step (kg N).
MINP_IN	Mineral phosphorus transported with water into reach during time step (kg P).
MINP_OUT	Mineral phosphorus transported with water out of reach during time step (kg P).
ALGAE_IN	Algal biomass transported with water into reach during time step (kg).
ALGAE_OUT	Algal biomass transported with water out of reach during time step (kg).
CBOD_IN	Carbonaceous biochemical oxygen demand of material transported into reach during time step (kg O_2).
CBOD_OUT	Carbonaceous biochemical oxygen demand of material transported out of reach during time step (kg O_2).
DISOX_IN	Amount of dissolved oxygen transported into reach during time step (kg O_2).
DISOX_OUT	Amount of dissolved oxygen transported out of reach during time step (kg O_2).
While more than one pesticide may be applied to the HRUs, due to the complexity of the pesticide equations only the pesticide listed in .bsn is routed through the stream network.	
SOLPST_IN	Soluble pesticide transported with water into reach during time step (mg active ingredient)
SOLPST_OUT	Soluble pesticide transported with water out of reach during time step (mg active ingredient).

Variable name	Definition
SORPST_IN	Pesticide sorbed to sediment transported with water into reach during time step (mg active ingredient).
SORPST_OUT	Pesticide sorbed to sediment transported with water out of reach during time step (mg active ingredient).
REACTPST	Loss of pesticide from water by reaction during time step (mg active ingredient).
VOLPST	Loss of pesticide from water by volatilization during time step (mg active ingredient).
SETTLPST	Transfer of pesticide from water to river bed sediment by settling during time step (mg active ingredient).
RESUSP_PST	Transfer of pesticide from river bed sediment to water by resuspension during time step (mg active ingredient).
DIFFUSEPST	Transfer of pesticide from water to river bed sediment by diffusion during time step (mg active ingredient).
REACBEDPST	Loss of pesticide from river bed sediment by reaction during time step (mg active ingredient).
BURYPST	Loss of pesticide from river bed sediment by burial during time step (mg active ingredient).
BED_PST	Pesticide in river bed sediment during time step (mg active ingredient).
BACTP_OUT	Number of persistent bacteria transported out of reach during time step.
BACTLP_OUT	Number of less persistent bacteria transported out of reach during time step.
CMETAL#1	Conservative metal #1 transported out of reach (kg).
CMETAL#2	Conservative metal #2 transported out of reach (kg).
CMETAL#3	Conservative metal #3 transported out of reach (kg).

The format of the main channel output file (.rch) is:

Variable name	Line #	Position	Format	F90 Format
RCH	All	space 7-10	4-digit integer	i4
GIS	All	space 12-19	8-digit integer	i8
MON	All	space 21-25	5-digit integer	i5
AREA	All	space 26-37	exponential	e12.4
FLOW_IN	All	space 38-49	exponential	e12.4
FLOW_OUT	All	space 50-61	exponential	e12.4
EVAP	All	space 62-73	exponential	e12.4
TLOSS	All	space 74-85	exponential	e12.4
SED_IN	All	space 86-97	exponential	e12.4
SED_OUT	All	space 98-109	exponential	e12.4
SEDCONC	All	space 110-121	exponential	e12.4
ORGN_IN	All	space 122-133	exponential	e12.4
ORGN_OUT	All	space 134-145	exponential	e12.4
ORGP_IN	All	space 146-157	exponential	e12.4
ORGP_OUT	All	space 158-169	exponential	e12.4
NO3_IN	All	space 170-181	exponential	e12.4
NO3_OUT	All	space 182-193	exponential	e12.4
NH4_IN	All	space 194-205	exponential	e12.4
NH4_OUT	All	space 206-217	exponential	e12.4
NO2_IN	All	space 218-229	exponential	e12.4
NO2_OUT	All	space 230-241	exponential	e12.4
MINP_IN	All	space 242-253	exponential	e12.4
MINP_OUT	All	space 254-265	exponential	e12.4
CHLA_IN	All	space 266-277	exponential	e12.4
CHLA_OUT	All	space 278-289	exponential	e12.4
CBOD_IN	All	space 290-301	exponential	e12.4
CBOD_OUT	All	space 302-313	exponential	e12.4
DISOX_IN	All	space 314-325	exponential	e12.4
DISOX_OUT	All	space 326-337	exponential	e12.4
SOLPST_IN	All	space 338-349	exponential	e12.4
SOLPST_OUT	All	space 350-361	exponential	e12.4
SORPST_IN	All	space 362-373	exponential	e12.4
SORPST_OUT	All	space 374-385	exponential	e12.4
REACTPST	All	space 386-397	exponential	e12.4

Variable name	Line #	Position	Format	F90 Format
VOLPST	All	space 398-409	exponential	e12.4
SETTLPST	All	space 410-421	exponential	e12.4
RESUSP_PST	All	space 422-433	exponential	e12.4
DIFFUSEPST	All	space 434-445	exponential	e12.4
REACBEDPST	All	space 446-457	exponential	e12.4
BURYPST	All	space 458-469	exponential	e12.4
BED_PST	All	space 470-481	exponential	e12.4
BACTP_OUT	All	space 482-493	exponential	e12.4
BACTLP_OUT	All	space 494-505	exponential	e12.4
CMETAL#1	All	space 506-517	exponential	e12.4
CMETAL#2	All	space 518-529	exponential	e12.4
CMETAL#3	All	space 530-541	exponential	e12.4

44.6 HRU IMPOUNDMENT OUTPUT FILE (.WTR)

The HRU impoundment output file contains summary information for ponds, wetlands and depressional/impounded areas in the HRUs. The file is written in spreadsheet format.

Following is a brief description of the output variables in the HRU impoundment output file.

Variable name	Definition
LULC	Four letter character code for the cover/plant on the HRU. (code from crop.dat file)
HRU	Hydrologic response unit number
GIS	GIS code reprinted from watershed configuration file (.fig). See explanation of subbasin command.
SUB	Topographically-defined subbasin to which the HRU belongs.
MGT	Management number. This is pulled from the management (.mgt) file. Used by the SWAT/GRASS interface to allow development of output maps by landuse/management type.
MON	Daily time step: the julian date Monthly time step: the month (1-12) Annual time step: year Average annual summary lines: total number of years averaged together
AREA	Drainage area of the HRU (km^2).
PNDPCP	Precipitation falling directly on the pond during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.
PND_IN	Pond inflow (mm H_2O). Surface runoff entering the pond during the time step. The depth of water is the volume divided by the area of the HRU.
PSED_I	Pond sediment inflow (metric tons/ha). Sediment transported into the pond during the time step. The loading is the mass divided by the area of the HRU.
PNDEVP	Evaporation from the pond surface during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.

Variable name	Definition
PNDSEP	Water that seeps through the bottom of the pond and recharges the shallow aquifer during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.
PND_OUT	Pond outflow (mm H_2O). Water leaving the pond and entering the reach during the time step. The depth of water is the volume divided by the area of the HRU.
PSED_O	Pond sediment outflow (metric tons/ha). Sediment transported out of the pond and entering the reach during the time step. . The loading is the mass divided by the area of the HRU.
PNDVOL	Volume of water in pond at end of time step (m^3 H_2O).
PNDORGN	Concentration of organic N in pond at end of time step (mg N/L or ppm).
PNDNO3	Concentration of nitrate in pond at end of time step (mg N/L or ppm).
PNDORGP	Concentration of organic P in pond at end of time step (mg P/L or ppm).
PNDMINP	Concentration of mineral P in pond at end of time step (mg P/L or ppm).
PNDCHLA	Concentration of chlorophyll-a in pond at end of time step (mg chl-a/L or ppm).
PNDSECI	Secchi-disk depth of pond at end of time step (m).
WETPCP	Precipitation falling directly on the wetland during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.
WET_IN	Wetland inflow (mm H_2O). Surface runoff entering the wetland during the time step. The depth of water is the volume divided by the area of the HRU.
WSED_I	Wetland sediment inflow (metric tons/ha). Sediment transported into the wetland during the time step. The loading is the mass divided by the area of the HRU.
WETEVP	Evaporation from the wetland during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.
WETSEP	Water that seeps through the bottom of the wetland and recharges the shallow aquifer during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.

Variable name	Definition
WET_OUT	Wetland outflow (mm H_2O). Water leaving the wetland and entering the reach during the time step. The depth of water is the volume divided by the area of the HRU.
WSED_O	Wetland sediment outflow (metric tons/ha). Sediment transported out of the wetland and entering the reach during the time step. . The loading is the mass divided by the area of the HRU.
WET_VOL	Volume of water in wetland at end of time step (m^3 H_2O).
WETORGN	Concentration of organic N in wetland at end of time step (mg N/L or ppm).
WETNO3	Concentration of nitrate in wetland at end of time step (mg N/L or ppm).
WETORGP	Concentration of organic P in wetland at end of time step (mg P/L or ppm).
WETMINP	Concentration of mineral P in wetland at end of time step (mg P/L or ppm).
WETCHLA	Concentration of chlorophyll-a in wetland at end of time step (mg chl-a/L or ppm).
WETSECI	Secchi-disk depth of wetland at end of time step (m).
POTPCP	Precipitation falling directly on the pothole during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.
POT_IN	Pothole inflow (mm H_2O). Surface runoff entering the pothole during the time step. The depth of water is the volume divided by the area of the HRU.
OSED_I	Pothole sediment inflow (metric tons/ha). Sediment transported into the pothole during the time step. The loading is the mass divided by the area of the HRU.
POTEVP	Evaporation from the pothole during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.
POTSEP	Water that seeps through the bottom of the pothole and enters the underlying soil during the time step (mm H_2O). The depth of water is the volume divided by the area of the HRU.
POT_OUT	Pothole outflow (mm H_2O). Water leaving the pothole and entering the reach during the time step. The depth of water is the volume divided by the area of the HRU.

Variable name	Definition
OSED_O	Pothole sediment outflow (metric tons/ha). Sediment transported out of the pothole and entering the reach during the time step. . The loading is the mass divided by the area of the HRU.
POTVOL	Volume of water in pothole at end of time step (m^3 H_2O).
POT_SA	Surface area of pothole at end of time step (ha).
HRU_SURQ	Surface runoff contribution to streamflow in the main channel from entire HRU during the time step (mm H_2O).
PLANT_ET	Amount of water removed by transpiration from plants during the time step (mm H_2O).
SOIL_ET	Amount of water removed by evaporation from the soil during the time step (mm H_2O).

The format of the HRU impoundment output file (.wtr) is:

Variable name	Line #	Position	Format	F90 Format
LULC	All	space 1-4	character	a4
HRU	All	space 5-8	4-digit integer	i4
GIS	All	space 10-17	8-digit integer	i8
SUB	All	space 19-22	4-digit integer	i4
MGT	All	space 24-27	4-digit integer	i4
MON	All	space 29-32	4-digit integer	i4
AREA	All	space 33-42	decimal(xxxxxx.xxx)	f10.3
PNDPCP	All	space 43-52	decimal(xxxxxx.xxx)	f10.3
PND_IN	All	space 53-62	decimal(xxxxxx.xxx)	f10.3
PSED_I	All	space 63-72	decimal(xxxxxx.xxx)	f10.3
PNDEVP	All	space 73-82	decimal(xxxxxx.xxx)	f10.3
PNDSEP	All	space 83-92	decimal(xxxxxx.xxx)	f10.3
PND_OUT	All	space 93-102	decimal(xxxxxx.xxx)	f10.3
PSED_O	All	space 103-112	decimal(xxxxxx.xxx)	f10.3
PNDVOL	All	space 113-122	exponential	e10.4
PNDORGN	All	space 123-132	decimal(xxxxxx.xxx)	f10.3
PNDNO3	All	space 133-142	decimal(xxxxxx.xxx)	f10.3
PNDORGP	All	space 143-152	decimal(xxxxxx.xxx)	f10.3
PNDMINP	All	space 153-162	decimal(xxxxxx.xxx)	f10.3
PNDCHLA	All	space 163-172	decimal(xxxxxx.xxx)	f10.3
PNDSECI	All	space 173-182	decimal(xxxxxx.xxx)	f10.3

Variable name	Line #	Position	Format	F90 Format
WETPCP	All	space 183-192	decimal(xxxxxx.xxx)	f10.3
WET_IN	All	space 193-202	decimal(xxxxxx.xxx)	f10.3
WSED_I	All	space 203-212	decimal(xxxxxx.xxx)	f10.3
WETEVP	All	space 213-222	decimal(xxxxxx.xxx)	f10.3
WETSEP	All	space 223-232	decimal(xxxxxx.xxx)	f10.3
WET_OUT	All	space 233-242	decimal(xxxxxx.xxx)	f10.3
WSED_O	All	space 243-252	decimal(xxxxxx.xxx)	f10.3
WET_VOL	All	space 253-262	exponential	e10.4
WETORGN	All	space 263-272	decimal(xxxxxx.xxx)	f10.3
WETNO3	All	space 273-282	decimal(xxxxxx.xxx)	f10.3
WETORGP	All	space 283-292	decimal(xxxxxx.xxx)	f10.3
WETMINP	All	space 293-302	decimal(xxxxxx.xxx)	f10.3
WETCHLA	All	space 303-312	decimal(xxxxxx.xxx)	f10.3
WETSECI	All	space 313-322	decimal(xxxxxx.xxx)	f10.3
POTPCP	All	space 323-332	decimal(xxxxxx.xxx)	f10.3
POT_IN	All	space 333-342	decimal(xxxxxx.xxx)	f10.3
OSED_I	All	space 343-352	decimal(xxxxxx.xxx)	f10.3
POTEVP	All	space 353-362	decimal(xxxxxx.xxx)	f10.3
POTSEP	All	space 363-372	decimal(xxxxxx.xxx)	f10.3
POT_OUT	All	space 373-382	decimal(xxxxxx.xxx)	f10.3
OSED_O	All	space 383-392	decimal(xxxxxx.xxx)	f10.3
POTVOL	All	space 393-402	exponential	e10.4
POT_SA	All	space 403-412	decimal(xxxxxx.xxx)	f10.3
HRU_SURQ	All	space 413-422	decimal(xxxxxx.xxx)	f10.3
PLANT_ET	All	space 423-432	decimal(xxxxxx.xxx)	f10.3
SOIL_ET	All	space 433-442	decimal(xxxxxx.xxx)	f10.3

44.7 RESERVOIR OUTPUT FILE (.RSV)

The reservoir output file contains summary information for reservoirs in the watershed. The file is written in spreadsheet format.

Following is a brief description of the output variables in the reservoir output file.

Variable name	Definition
RES	Reservoir number (assigned in .fig file)
MON	Daily time step: the julian date Monthly time step: the month (1-12) Annual time step: four-digit year
VOLUME	Volume of water in reservoir at end of time step (m^3 H_2O).
FLOW_IN	Average flow into reservoir during time step (m^3/s H_2O).
FLOW_OUT	Average flow out of reservoir during time step (m^3/s H_2O).
PRECIP	Precipitation falling directly on the reservoir during the time step (m^3 H_2O).
EVAP	Evaporation from the reservoir during the time step (m^3 H_2O).
SEEPAGE	Water that seeps through the bottom of the reservoir and enters the shallow aquifer during the time step (m^3 H_2O).
SED_IN	Reservoir sediment inflow (metric tons). Sediment transported into the reservoir during the time step.
SED_OUT	Reservoir sediment outflow (metric tons). Sediment transported out of the reservoir during the time step.
ORGN_IN	Amount of organic nitrogen transported into reservoir during the time step (kg N).
ORGN_OUT	Amount of organic nitrogen transported out of reservoir during the time step (kg N).
ORGP_IN	Amount of organic phosphorus transported into reservoir during the time step (kg P).
ORGP_OUT	Amount of organic phosphorus transported out of reservoir during the time step (kg P).
NO3_IN	Amount of nitrate transported into reservoir during the time step (kg N).

Variable name	Definition
NO3_OUT	Amount of nitrate transported out of reservoir during the time step (kg N).
NO2_IN	Amount of nitrite transported into reservoir during the time step (kg N).
NO2_OUT	Amount of nitrite transported out of reservoir during the time step (kg N).
NH3_IN	Amount of ammonia transported into reservoir during the time step (kg N).
NH3_OUT	Amount of ammonia transported out of reservoir during the time step (kg N).
MINP_IN	Amount of mineral phosphorus transported into reservoir during the time step (kg P).
MINP_OUT	Amount of mineral phosphorus transported out of reservoir during the time step (kg P).
CHLA_IN	Amount of chlorophyll *a* transported into reservoir during the time step (kg chla).
CHLA_OUT	Amount of chlorophyll *a* transported out of reservoir during the time step (kg chla).
SECCHIDEPTH	Secchi-disk depth of reservoir at end of time step (m).
PEST_IN	Amount of pesticide transported into reservoir during the time step (mg pesticide active ingredient).
REACTPST	Loss of pesticide from water by reaction during time step (mg active ingredient).
VOLPST	Loss of pesticide from water by volatilization during time step (mg active ingredient).
SETTLPST	Transfer of pesticide from water to reservoir bed sediment by settling during time step (mg active ingredient).
RESUSP_PST	Transfer of pesticide from reservoir bed sediment to water by resuspension during time step (mg active ingredient).
DIFFUSEPST	Transfer of pesticide from water to reservoir bed sediment by diffusion during time step (mg active ingredient).
REACBEDPST	Loss of pesticide from reservoir bed sediment by reaction during time step (mg active ingredient).
BURYPST	Loss of pesticide from reservoir sediment by burial during time step (mg active ingredient).

Variable name	Definition
PEST_OUT	Amount of pesticide transported out of reservoir during the time step (mg pesticide active ingredient).
PSTCNCW	Average concentration of pesticide in reservoir water during time step (mg active ingredient/m^3 H_2O or ppb).
PSTCNCB	Average concentration of pesticide in reservoir bed sediment during time step (mg active ingredient/m^3 H_2O or ppb).

The format of the reservoir output file (.rsv) is:

Variable name	Line #	Position	Format	F90 Format
RES	All	space 7-14	integer	i8
MON	All	space 16-19	integer	i4
VOLUME	All	space 20-31	exponential	e12.4
FLOW_IN	All	space 32-43	exponential	e12.4
FLOW_OUT	All	space 44-55	exponential	e12.4
PRECIP	All	space 56-67	exponential	e12.4
EVAP	All	space 68-79	exponential	e12.4
SEEPAGE	All	space 80-91	exponential	e12.4
SED_IN	All	space 92-103	exponential	e12.4
SED_OUT	All	space 104-115	exponential	e12.4
ORGN_IN	All	space 116-127	exponential	e12.4
ORGN_OUT	All	space 128-139	exponential	e12.4
ORGP_IN	All	space 140-151	exponential	e12.4
ORGP_OUT	All	space 152-163	exponential	e12.4
NO3_IN	All	space 164-175	exponential	e12.4
NO3_OUT	All	space 176-187	exponential	e12.4
NO2_IN	All	space 188-199	exponential	e12.4
NO2_OUT	All	space 200-211	exponential	e12.4
NH3_IN	All	space 212-223	exponential	e12.4
NH3_OUT	All	space 224-235	exponential	e12.4
MINP_IN	All	space 236-247	exponential	e12.4
MINP_OUT	All	space 248-259	exponential	e12.4
CHLA_IN	All	space 260-271	exponential	e12.4
CHLA_OUT	All	space 272-283	exponential	e12.4
SECCHIDEPTH	All	space 284-295	exponential	e12.4
PEST_IN	All	space 296-307	exponential	e12.4

Variable name	Line #	Position	Format	F90 Format
REACTPST	All	space 308-319	exponential	e12.4
VOLPST	All	space 320-331	exponential	e12.4
SETTLPST	All	space 332-343	exponential	e12.4
RESUSP_PST	All	space 344-355	exponential	e12.4
DIFFUSEPST	All	space 356-367	exponential	e12.4
REACBEDPST	All	space 368-379	exponential	e12.4
BURYPST	All	space 380-391	exponential	e12.4
PEST_OUT	All	space 392-403	exponential	e12.4
PSTCNCW	All	space 404-415	exponential	e12.4
PSTCNCB	All	space 416-427	exponential	e12.4

SWAT MODEL CALIBRATION

Calibration of a model run can be divided into several steps:

- water balance and stream flow
- sediment
- nutrients
- pesticides

WATER BALANCE AND STREAM FLOW

To calibrate the water balance and stream flow you need to have some understanding of the actual conditions occurring in the watershed. Ideally, you have data from a stream gage located within or at the outlet of your watershed.

> The U.S. Geological Survey maintains a website (http://water.usgs.gov/) with daily records for all stream gages in the U.S. available for downloading.

Calibration for water balance and stream flow is first done for average annual conditions. Once the run is calibrated for average annual conditions, the user can shift to monthly or daily records to fine-tune the calibration.

The average annual observed and simulated results should be summarized in a manner similar to the following table:

	Total Water Yield	Baseflow	Surface Flow
Actual	200 mm	80 mm	120 mm
SWAT	300 mm	20 mm	280 mm

(When calibrating, we usually summarize data as depth of water in millimeters over the drainage area. Feel free to use whatever units you prefer.)

> If you are calibrating at the watershed outlet, the SWAT values for the table are provided in the .std file. These values are listed in the table titled "Ave Annual Basin Values" located near the end of the file.
>
> If you are calibrating a gage located within the watershed, the total water yield can be calculated from the FLOW_OUT variable in the reach (.rch) file. The values for Baseflow and Surface Flow have to be estimated from the HRU output (.sbs) file or the subbasin output file (.bsb). To estimate the contributions by baseflow and streamflow, the average annual values for GWQ, SURQ and WYLD need to be averaged so that an areally weighted value for the drainage area of interest is obtained. The surface flow and baseflow then need to be converted to fractions by dividing by the total water yield (WYLD). These fractions are then multiplied by the total water yield obtained from the reach output file. The values for GWQ and SURQ cannot be used directly because in-stream precipitation, evaporation, transmission losses, etc. will alter the net water yield from that predicted by the WYLD variable in the HRU or Subbasin Output files.

There are a number of methods available for partitioning observed stream flow into fractions contributed by baseflow and surface runoff. If daily steam flow is available, a baseflow filter program can be run which performs this analysis.

I. Basic Water Balance & Total Flow Calibration

Calibrate surface runoff:

Step 1: Adjust the curve number (CN2 in .sub or .mgt) until surface runoff is acceptable. Appendix A contains tables of curve number values for a wide variety of land covers. Appendix B contains tables summarizing ranges for the general categories of land cover and lists the land cover category for all plants in the SWAT Land Cover/Plant database.

If surface runoff values are still not reasonable after adjusting curve numbers, adjust:
- -soil available water capacity (±0.04) (SOL_AWC in .sol) and/or
- -soil evaporation compensation factor (ESCO in .sub).

Calibrate subsurface flow:

Step 2: Once surface runoff is calibrated, compare measured and simulated values of baseflow.

If simulated baseflow is too high:
- -increase the groundwater "revap" coefficient (GW_REVAP in .gw)—the maximum value that GW_REVAP should be set at is 0.20.
- -decrease the threshold depth of water in the shallow aquifer for "revap" to occur (REVAPMN in .gw)—the minimum value that REVAPMN should be set at is 0.0.
- -increase the threshold depth of water in the shallow aquifer required for base flow to occur (GWQMN in .gw)—the maximum value that GWQMN should be set at is left to user discretion.

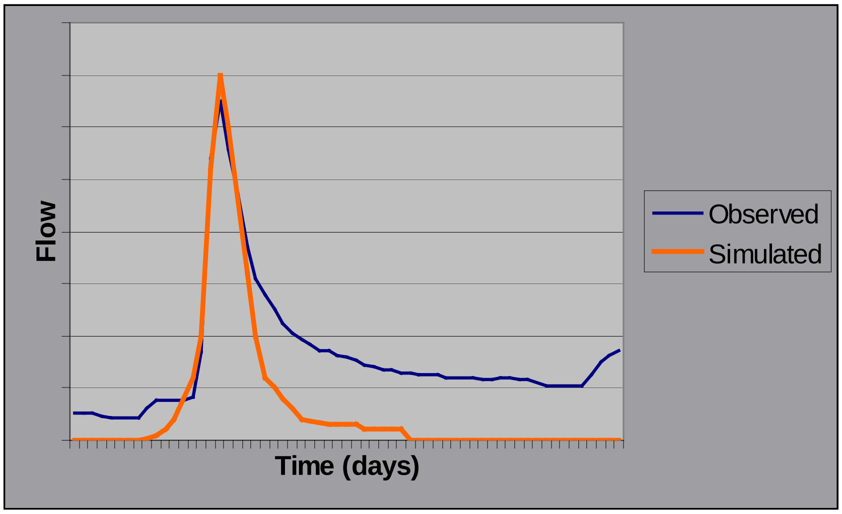
If simulated baseflow is too low, check the movement of water into the aquifer.

If groundwater recharge (GWQ in .sbs or .bsb) is greater than or equal to the desired baseflow:
- -decrease the groundwater "revap" coefficient (GW_REVAP in .gw)—the minimum value that GW_REVAP should be set at is 0.02.
- -increase the threshold depth of water in the shallow aquifer for "revap" to occur (REVAPMN in .gw).
- -decrease the threshold depth of water in the shallow aquifer required for base flow to occur (GWQMN in .gw)—the minimum value that GWQMN should be set at is 0.0.

Step 3: Repeat steps 1 and 2 until values are acceptable. It may take several reiterations to get the surface runoff and baseflow correct.

II. Temporal Flow Calibration

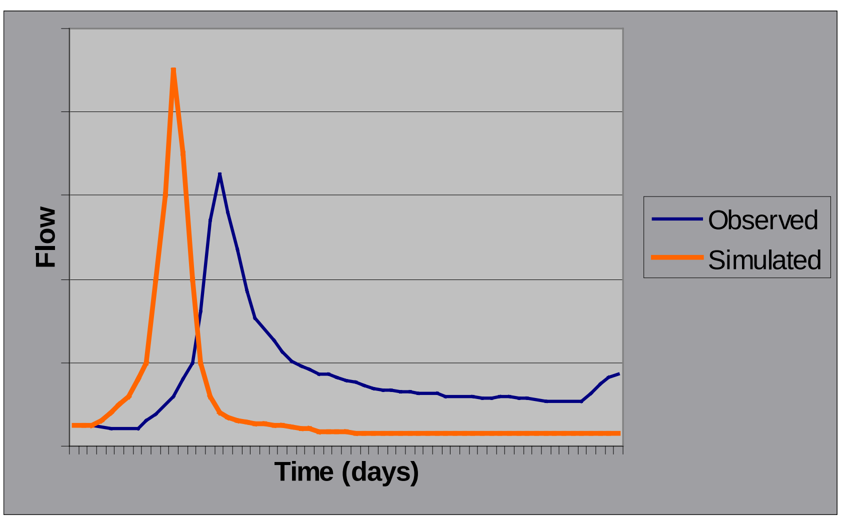
Once average annual and annual surface runoff and baseflow are realistic, the temporal flow should look reasonable as well. A few problems that may still be present include:



1) Peaks are reasonable, but the recessions "bottom out": Check the transmission losses/values for channel hydraulic conductivity (CH_K in .rte). The value for channel hydraulic conductivity is an *effective* hydraulic conductivity for movement of water **out** of the stream bed.

For perennial streams receiving groundwater contribution to flow, the groundwater enters the stream through the sides and bottom of the stream bed, making the effective hydraulic conductivity of the channel beds to water losses equal to zero. The only time the channel hydraulic conductivity would be greater than zero is for ephemeral and transient streams that do not receive continuous groundwater contributions to streamflow.

A second variable that will affect the shape of the hydrograph is the baseflow alpha factor (ALPHA_BF in .gw).



2) In snow melt months, the peaks are too high and recessions are too low: Check the values for maximum and minimum melt rates for snow (SMFMX and SMFMN in .bsn). These values may need to be lowered. Another variable that will impact snow melt is the temperature lapse rate (TLAPS in .sub). These values may need to be increased. Finally, the baseflow alpha factor may need to be modified (ALPHA_BF in .gw).

III. SPATIAL FLOW CALIBRATION

If you are calibrating a watershed with multiple stream gages, calibrate streamflow for the gage furthest upstream. Once that gage is calibrated, move downstream to the next gage and calibrate for that area. It is important that, as you calibrate downstream gages, you do not change parameters within the files associated with the drainage area of the upstream gages already calibrated.

SEDIMENT

There are two sources of sediment in the SWAT simulation: loadings from HRUs/subbasins and channel degradation/deposition. Once the ratio of surface runoff to baseflow contribution to streamflow is being simulated correctly, the sediment contribution (loadings from HRUs/subbasins) should be close to measured values. In most situations, the user will probably have little information about channel degradation/deposition. For those unable to go out and assess the channel, we suggest that you adjust the loadings from the subbasins until they look reasonable and then assume that the remaining difference between actual and observed is due to channel degradation/deposition.

The average annual observed and simulated results should be summarized in a manner similar to the following table. A more detailed table which contains the loadings by land use on a given soil type may be used also.

	Sediment	
Loadings from mixed forest	187 metric tons/yr	0.14 metric tons/ha/yr
Loadings from bermuda pasture	354 metric tons/yr	0.23 metric tons/ha/yr
Loadings from range	1459 metric tons/yr	0.35 metric tons/ha/yr
Loading from HRUs/subbasins	2,000 metric tons/yr	0.28 metric tons/ha/yr
Amount of sediment leaving reach	2,873 metric tons/yr	
Actual	2,321 metric tons/yr	

Sediment loadings from the HRUs/subbasins can be calculated by summing values for SYLD in either the .sbs or .bsb file. The amount of sediment leaving the reach can be obtained from values reported for SED_OUT in the .rch file.

CHECK RESERVOIR/POND SIMULATION:

Reservoirs and ponds have a big impact on sediment loadings. If the amount of sediment being simulated in the watershed is off, first verify that you are accounting for all the ponds and reservoirs in the watershed and that they are being simulated properly.

CALIBRATE SUBBASIN LOADINGS:

While surface runoff is the primary factor controlling sediment loadings to the stream, there are a few other variables that affect sediment movement into the stream.

1) Tillage has a great impact on sediment transport. With tillage, plant residue is removed from the surface causing erosion to increase. Verify that the tillage practices are being accurately simulated.

2) USLE equation support practices (P) factor (USLE_P in the .sub file): Verify that you have accurately accounted for contouring and terracing in agricultural areas. In general, agricultural land with a slope greater that 5% will be terraced.

3) USLE equation slope length factor (SLSUBBSN in .sub file): There is usually a large amount of uncertainty in slope length measurements. The slope length will also be affected by support practices used in the HRU.

4) Slope in the HRUs (SLOPE in .sub file): Verify that the slopes given for the subbasin are correct.

5) USLE equation cropping practices (C) factor (USLE_C in crop.dat): In some cases, the minimum C value reported for the plant cover may not be accurate for your area.

CALIBRATE CHANNEL DEGRADATION/DEPOSITION:

Channel degradation will be significant during extreme storm events and in unstable subbasins. Unstable subbasins are those undergoing a significant change in land use patterns such as urbanization. Variables that affect channel degradation/deposition include:

1) The linear and exponential parameters used in the equation to calculate sediment reentrained in channel sediment routing (SPCON and SPEXP in .bsn file). These variables affect sediment routing in the entire watershed.

2) The channel erodibility factor (CH_EROD in .rte)

3) The channel cover factor (CH_COV in .rte)

NUTRIENTS

The nutrients of concern in SWAT are nitrate, soluble phosphorus, organic nitrogen and organic phosphorus. When calibrating for a nutrient, keep in mind that changes made will have an effect all the nutrient levels.

Nutrient calibration can be divided into two steps: calibration of nutrient loadings and calibration of in-stream water quality processes.

CALIBRATE NUTRIENT LOADINGS (ALL NUTRIENTS):

1) Check that the initial concentrations of the nutrients in the soil are correct. These are set in the soil chemical input file (.chm) and in the soil input file (.sol):

nitrate (SOL_NO3 in .sol)
soluble P (SOL_MINP in .chm)
organic N (SOL_ORGN in .chm)
organic P (SOL_ORGP in .chm)

2) Verify that fertilizer applications are correct. Check amounts and the soil layer that the fertilizer is applied to. The fertilizer may be applied to the top 10mm of soil or incorporated in the first soil layer. The variable FRT_LY1 identifies the fraction of fertilizer applied to the top 10mm of soil. (If this variable is left at zero, the model will set FRT_LY1 = 0.20).

3) Verify that tillage operations are correct. Tillage redistributes nutrients in the soil and will alter the amount available for interaction or transport by surface runoff.

4) Alter the biological mixing efficiency (BIOMIX in .bsn file). Biological mixing acts the same as a tillage operation in that it incorporates residue and nutrients into the soil. This variable controls mixing due to biological activity in the entire watershed.

CALIBRATE NUTRIENT LOADINGS (NITRATE):

In addition to the variables mentioned above,

1) Modify the nitrogen percolation coefficient (NPERCO in .bsn file)

CALIBRATE NUTRIENT LOADINGS (SOLUBLE P):

In addition to the variables mentioned in the section for all nutrients,

1) Modify the phosphorus percolation coefficient (PPERCO in .bsn file)

2) Modify the phosphorus soil partitioning coefficient (PHOSKD in .bsn file).

CALIBRATE NUTRIENT LOADINGS (ORGANIC N & P):

Organics are transported to the stream attached to sediment, so the movement of sediment will greatly impact the movement of organics.

CALIBRATE IN-STREAM NUTRIENT PROCESSES:

SWAT includes in-stream nutrient cycling processes as described in the QUAL2E documentation. Variables in the watershed water quality (.wwq) and stream water quality (.swq) files control these processes.

Tables of Runoff Curve Number Values[‡]

Table 1: Runoff curve numbers for cultivated agricultural lands

Cover			Hydrologic Soil Group			
Land Use	**Treatment or practice**	**Hydrologic condition**	**A**	**B**	**C**	**D**
Fallow	Bare soil	- - - -	77	86	91	94
	Crop residue cover[*]	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row	Poor	72	81	88	91
		Good	67	78	85	89
	Straight row w/ residue	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured w/ residue	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured & terraced	Poor	66	74	80	82
		Good	62	71	78	81
	Contoured & terraced w/ residue	Poor	65	73	79	81
		Good	61	70	77	80
Small grains	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Straight row w/ residue	Poor	64	75	83	86
		Good	60	72	80	84
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured w/ residue	Poor	62	73	81	84
		Good	60	72	80	83
	Contoured & terraced	Poor	61	72	79	82
		Good	59	70	78	81
	Contoured & terraced w/ residue	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation	Straight row	Poor	66	77	85	89
		Good	58	72	81	85
	Contoured	Poor	64	75	83	85
		Good	55	69	78	83
	Contoured & terraced	Poor	63	73	80	83
		Good	51	67	76	80

[‡] These tables are reproduced from *Urban Hydrology for Small Watersheds*, USDA Soil Conservation Service Engineering Division, Technical Release 55, June 1986.

[*] Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.

Table 2: Runoff curve numbers for other agricultural lands

Cover Type	Hydrologic condition	A	B	C	D
		Hydrologic Soil Group			
Pasture, grassland, or range—continuous forage for grazing[1]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from grazing and generally mowed for hay.	- - - -	30	58	71	78
Brush—brush-weed-grass mixture with brush the major element[2]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30	48	65	73
Woods—grass combination (orchard or tree farm)	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods[3]	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	- - - -	59	74	82	86

[1] *Poor:* < 50% ground cover or heavily grazed with no mulch
Fair: 50 to 75% ground cover and not heavily grazed
Good: > 75% ground cover and lightly or only occasionally grazed

[2] *Poor:* < 50% ground cover
Fair: 50 to 75% ground cover
Good: > 75% ground cover

[3] *Poor:* Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Table 3: Runoff curve numbers for urban areas

Cover Type	Hydrologic condition	Average % impervious area	A	B	C	D
			Hydrologic Soil Group			
Fully developed urban areas						
Open spaces (lawns, parks, golf courses, cemeteries, etc.)[4]	Poor		68	79	86	89
	Fair		49	69	79	84
	Good		39	61	74	80
Impervious areas:						
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)	- - - -		98	98	98	98
Paved streets and roads; curbs and storm sewers (excluding right-of-way)	- - - -		98	98	98	98
Paved streets and roads; open ditches (including right-of-way)	- - - -		83	89	92	93
Gravel streets and roads (including right-of-way)	- - - -		76	85	89	91
Dirt streets and roads (including right-of way)	- - - -		72	82	87	89
Urban districts:						
Commercial and business		85%	89	92	94	95
Industrial		72%	81	88	91	93
Residential Districts by average lot size:						
1/8 acre (0.05 ha) or less (town houses)		65%	77	85	90	92
1/4 acre (0.10 ha)		38%	61	75	83	87
1/3 acre (0.13 ha)		30%	57	72	81	86
1/2 acre (0.20 ha)		25%	54	70	80	85
1 acre (0.40 ha)		20%	51	68	79	84
2 acres (0.81 ha)		12%	46	65	77	82
Developing urban areas:						
Newly graded areas (pervious areas only, no vegetation)			77	86	91	94

[4] *Poor:* grass cover < 50%
Fair: grass cover 50 to 75%
Good: grass cover > 75%

Table 4: Runoff curve numbers for arid and semiarid rangelands

Cover		Hydrologic Soil Group			
Cover Type	**Hydrologic condition**[5]	**A**	**B**	**C**	**D**
Herbaceous—mixture of grass, weeds, and low-growing brush, with brush the minor element.	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush.	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both: grass understory.	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory.	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbrush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus.	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

[5] *Poor:* < 30% ground cover (litter, grass, and brush overstory)
Fair: 30 to 70% ground cover
Good: > 70% ground cover

Curve Number Calibration

Table 1: Guideline runoff curve number ranges

	Hydrologic Soil Group			
Land Cover Category	**A**	**B**	**C**	**D**
Row crop	61-72	70-81	77-88	80-91
Small grain/close grown crop	58-65	69-76	77-84	80-88
Perennial grasses	30-68	58-79	71-86	78-89
Annual grasses (close-seeded legumes)	51-66	67-77	76-85	80-89
Range	39-68	61-79	74-86	80-89
Semiarid/arid range	39-74	62-80	74-87	85-93
Brush	30-48	48-67	65-77	73-83
Woods	25-45	55-66	70-77	77-83
Orchard/tree farm	32-57	58-73	72-82	79-86
Urban	46-89	65-92	77-94	82-95